BIS CONFERENCE PAPERS

Vol. 8 – March 2000

INTERNATIONAL FINANCIAL MARKETS AND THE IMPLICATIONS FOR MONETARY AND FINANCIAL STABILITY

BANK FOR INTERNATIONAL SETTLEMENTS
Monetary and Economic Department
Basel, Switzerland

Papers in this volume were prepared for the meeting of central bank economists held at the Bank for International Settlements in October 1999. The papers are on subjects of topical interest but are technical in character. The views expressed in them are those of their authors and not necessarily the views of the BIS or of the central banks represented at the meeting.

Copies of publications are available from:

Bank for International Settlements
Information, Press & Library Services
CH-4002 Basel, Switzerland

Fax: +41 61 / 280 91 00 and +41 61 / 280 81 00

ISSN 1026-3993
ISBN 92-9131-099-9

BIS CONFERENCE PAPERS

Vol. 8 – March 2000

INTERNATIONAL FINANCIAL MARKETS AND THE IMPLICATIONS FOR MONETARY AND FINANCIAL STABILITY

BANK FOR INTERNATIONAL SETTLEMENTS
Monetary and Economic Department
Basel, Switzerland

TABLE OF CONTENTS

Foreword

On 25–26 October 1999, the BIS hosted its annual autumn meeting of economists with representatives from a number of central banks. The topic of the meeting, "International Financial Markets and the Implications for Monetary and Financial Stability", was chosen in recognition of the growing role played by asset markets and financial factors in shaping the environment in which monetary policy operates and in triggering episodes of financial instability. In order to stimulate further debate on and study of these questions, which are so important for central banks, the BIS is pleased to make available the papers presented at the meeting.

Participants in the meeting

Australia:	Ms Luci ELLIS
Austria:	Mr Franz SCHARDAX
Belgium:	Mr Thierry TIMMERMANS Ms Catherine RIGO
Canada:	Mr John MURRAY Mr Mark ZELMER
ECB:	Mr Vincent BROUSSEAU Mr Nuno CASSOLA
France:	Mr Jean CORDIER Mr Eric JONDEAU
Germany:	Mr Dietrich DOMANSKI Mr Manfred KREMER
Italy:	Mr Aviram LEVY Mr Marcello PERICOLI
Japan:	Mr Takamasa HISADA Mr Hitoshi SASAKI
Netherlands:	Mr Peter J G VLAAR Ms Annemarie M C VAN DER ZWET
Spain:	Mr José Luis ESCRIVÁ BELMONTE Mr Roberto BLANCO
Sweden:	Mr Hans DILLÉN Mr Peter SELLIN
Switzerland:	Mr Bertrand RIME Mr Dominik EGLI
United Kingdom:	Ms Anne VILA Mr Andrew CLARE
United States:	Mr Kei-Mu YI *(New York)* Mr Bill ENGLISH *(Washington)* Mr Mico LORETAN *(Washington)*
BIS:	Mr William WHITE (Chairman) Mr Renato FILOSA Mr Joseph BISIGNANO Mr Claudio BORIO Mr Palle ANDERSEN

Global liquidity in the 1990s: geographical allocation and long-run determinants

Fabio Fornari and Aviram Levy[1]

1. Introduction and main conclusions

One of the most significant aspects of financial globalisation has been the extremely rapid expansion of international liquidity. The enormous increase in liquid assets available to international market participants is worrisome for several reasons: it erodes central banks' ability to exercise monetary control; it triggers potential inflationary pressures that could easily be triggered if expectations change; finally, it facilitates the opening of speculative positions and may cause the quality of credit to decline. These last two channels can create instability in the financial and real markets.

Other studies conducted by the Bank of Italy's Research Department have analysed this phenomenon,[2] focusing on the multiplication process of cross-border deposits to evaluate its stability, the implications for monetary control by central banks and the risk of inflation. The analyses found that the international multiplier is broadly stable for cross-border deposits, which make up a small share of the money available to households and firms. They therefore pose a limited threat to the stability of prices through the traditional channel whereby excess money leads to inflation. Alongside this relatively reassuring conclusion, however, the studies revealed important risks in two other areas.

First, in industrial nations there was evidence of a very rapid expansion in other types of financial assets held by households, especially bonds: the gross financial assets of the G6 doubled as a proportion of GDP between 1980 and 1994. Most of these assets could easily be sold and therefore represent an enormous reserve of potential liquidity that could fuel inflationary pressures through channels other than the traditional one linking prices only, or primarily, to the money supply. Second, the analyses reported evidence for the potential risks of the growth of cross-border interbank deposits: neglected by standard monetary analysis, these deposits have not only expanded very rapidly but unlike household deposits they have reached very high levels in relation to the corresponding measure of national liquidity. Cross-border interbank deposits are therefore a potential cause of financial instability both because they can fuel speculative bubbles (an all too real possibility considering current levels of share and bond prices) and because they can play an important role in the international transmission of financial turbulence, as recent crises suggest.

This paper continues the research on international liquidity, aiming to improve understanding of the latter by analysing cross-border financial flows differentiated by origin and destination. The approach is also a first step towards constructing a framework for international analysis that extends the analysis of the flow of funds within each financial system to the global level.

The examination of international liquidity by origin and destination is carried out in two stages, which correspond to the two parts of this paper. The first part studies flows between large geographical areas in order to better understand the role that cross-border flows have played in the international allocation of financial resources and, more recently, in the transmission of turbulence. We have devoted particular attention to Japan (where strong monetary expansion is said to have primarily translated into

---

[1] This paper draws heavily on *Liquidità internazionale: distribuzione geografica e determinanti di fondo*, by F Fornari, A Levy and C Monticelli, preparatory paper for Bank of Italy's 1998 Annual Report, April 1999, mimeo. The authors wish to thank the participants at the Autumn Meeting of Central Bank Economists, held at the BIS in Basel on 25-26 October 1999, for their comments; the editorial assistance of Bianca Bucci and Giovanna Poggi is gratefully acknowledged.

[2] The literature on international liquidity dates back to the early 1970s; see, for instance, Fratianni and Savona (1972).

capital outflows rather than domestic demand) and to the offshore banking centres and their role as international intermediaries, especially towards the emerging economies. The singularity of recent episodes of financial instability has also prompted us to adopt a more cyclical viewpoint, focusing on the phases of the preparation, explosion and re-absorption of the Asian and Russian crises.

The second part of this analysis utilises a higher degree of geographical differentiation and studies the flows to and from each of the G6 countries in order to understand fully the structural factors that determine the allocation of funds in any given country. Using a longer time horizon makes it possible to conduct econometric analysis to uncover the factors underlying the holdings of cross-border deposits.

The main conclusions are as follows:

- In the period between 1991 and 1994, which was characterised by the stagnation of cross-border interbank flows in conjunction with the economic slowdown in the industrial countries, a total of $170 billion flowed out of Japan towards other industrial nations and Asian offshore banking centres. The latter played a major role in intermediating flows at the international level, borrowing funds from Japan and redirecting them to other industrial countries and the emerging economies.
- In the period between 1995 and 1997, global interbank activity expanded rapidly, characterised once again by net outflows from Japan. During this period, however, the banking system of the industrial countries (excluding Japan) played the role of intermediary in the reallocation of flows, having made loans to offshore centres that were nearly equal to fund-raising from Japan ($50 billion). The flows to emerging economies were enormous: $150 billion to banks and $130 billion to non-bank agents. Large capital flows (around $100 billion) were recorded in favour of non-bank agents located in offshore centres, among which some non-bank financial intermediaries such as hedge funds are also probably included.
- Following the outbreak of the Asian crisis in the first half of 1998, there was a generalised contraction in banks' gross international exposure; the year as a whole witnessed sizeable net capital outflows from offshore centres towards banks located in Japan and other OECD countries (around $190 billion) and a sharp reduction in loans to both banks ($53 billion) and non-bank borrowers (around $30 billion) in the emerging economies.
- An analysis of flows broken down by the nationality of the intermediaries' parent company, rather than by the country of location, shows that flows between parent companies and the foreign branches of Japanese banks represent a considerable share of international flows, suggesting that the evolution of the Japanese banking system is a key factor in analysing cross-border flows.
- Preliminary econometric estimates aimed at identifying the structural determinants of the international movement of bank capital - conducted for a longer time series (1985 to 1998) and using a more detailed geographical breakdown of flows – suggest that financial variables (such as the ratio of stock market capitalisation to GDP) have a greater explanatory power than more traditional macroeconomic variables (output, international trade, interest rate differentials). However, the group of significant variables differs from country to country and also depends on the criterion chosen for geographical disaggregation (that is, the depositor's residence or the intermediary's location). This suggests that other determinants that are specific to the country and to the nature of the cross-border relationship (with other banks or other subjects) can also be significant.

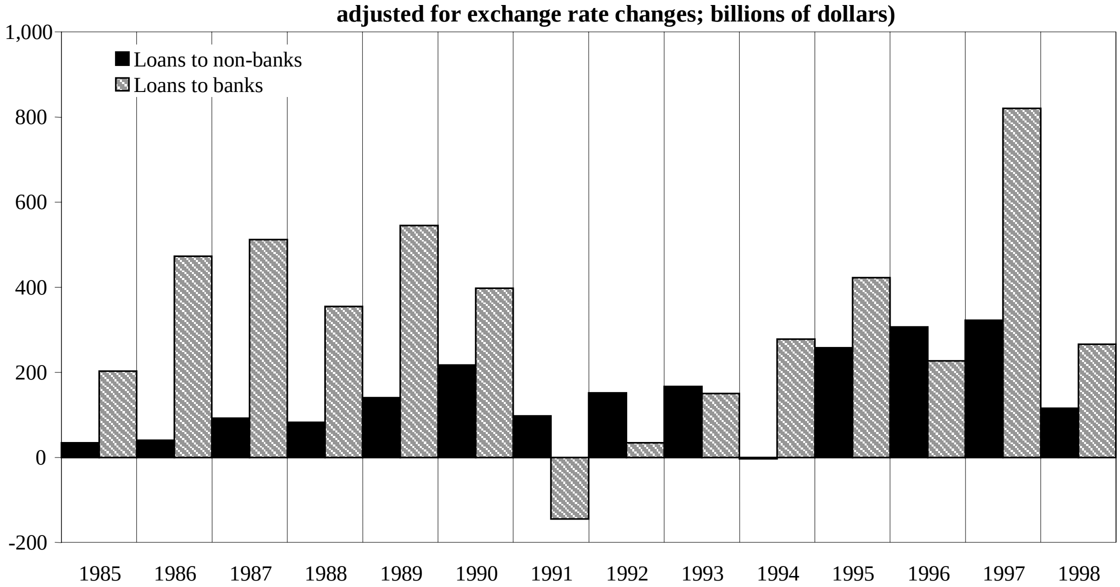
2. Flows of bank capital between large economic areas

In this section we first identify the principal cycles that have characterised developments in the international banking sector in the 1990s. We then examine bank capital flows between the world's large economic areas, paying special attention to the hypothesis that between 1995 and 1997 the Japanese banking system furnished liquidity to the international banking system, which in turn reinvested these funds in the emerging market economies. The sudden unwinding of these positions (de-leveraging) in 1998 seems to have amplified and propagated the effects of the international financial crisis.

2.1 International banking activity in the 1990s: cycles and underlying factors

After growing at exceptional rates in the second half of the 1980s (between 1984 and 1989 the stock of cross-border interbank assets grew on average by more than 20% annually and that with respect to non-banks rose at a 15% rate), stocks of loans to non-residents increased more slowly in the 1990s, rising at an annual rate of slightly less than 6% for banks and over 10% for non-banks. As shown in Chart 1 (the shaded histograms represent the change in gross lending to non-resident banks, the light histograms that to non-banks), after the high volumes observed in the second half of the 1980s, in the 1990s bank lending to non-residents decreased. An exception to this trend was 1997, when unprecedented flows were recorded. In the period considered, the flow of interbank loans was on average larger and showed greater volatility than lending to non-banks.

Chart 1: International lending activity
(annual changes in cross-border claims of reporting banks adjusted for exchange rate changes; billions of dollars)



Source: BIS, *International Banking and Financial Market Developments.*

Chart 1 enables us to identify three different sub-periods in this decade: 1991 to 1994, distinguished by a pronounced stagnation in activity; 1995 to 1997, characterised by rapid expansion; and 1998, when activity again stagnated owing to the international financial crisis.

2.1.1 From stagnation to strong expansion: 1991–94 and 1995–97

The stagnation recorded between 1991 and 1994 is attributable to a variety of factors (see BIS (1995)): the cyclical weakness of the world economy, which not only had direct effects but also was accompanied by a deterioration of the credit standing of many banking groups and, in some countries, by a large fall in prices of securities and real estate; and the contraction of international activity by Japanese banks, which is also linked to the collapse of Japan’s financial and real estate sectors at the end of the 1980s.

The decline in international banking activity in the early 1990s was mitigated by two opposing phenomena: first, the 1992–93 currency crisis in Europe triggered a massive recourse to bank financing both by investors who were betting on the depreciation of the currencies under attack, and by other market participants who sought to insure themselves against this eventuality by hedging against exchange rate risk; second, increased demand for bank funds was also created by the rise in international repurchase transactions, linked to the growth in global demand for government bonds.

By contrast, between 1995 and 1997 international banking activity expanded rapidly. It was driven by Japan's robust monetary expansion, aimed at countering the slowdown in its economy and the difficulties in its banking system, and more generally by favourable international economic conditions (see Giannini and Monticelli (1997); Tristani (1998)). As shown in Chart 1, banking activity was especially strong in 1997, with unprecedented growth in interbank lending (more than $800 billion) and lending to non-banks (over $300 billion). This enormous increase (some $400 billion was lent in the fourth quarter alone) was the product of two factors in particular: (i) loans granted by the parent companies of Japanese banks to their foreign branch offices (over $80 billion in the fourth quarter), made necessary owing to the funding difficulties of the latter (induced by the deterioration in their creditworthiness) and aided by the abundance of liquidity in Japan; (ii) the explosion of the Asian crisis, which generated large transfers of interbank funds between geographical areas to accommodate changes in portfolio composition and triggered a "flight to quality" that translated into a greater preference for liquidity.

An important phenomenon that characterised international banking activity in the period between 1995 and 1997, and which was prolonged and accentuated with the crisis of 1998, is the trend of banks in the industrial countries to employ a growing share of their external assets in the form of securities rather than traditional loans to customers: as can be seen in Table 1, between the end of 1995 (when the BIS began collecting data) and mid-1998, securities increased from 28% to 35% of the total stock of assets, and from 46% to almost 70% of flows.[3]

Table 1
Securitisation of external assets of reporting banks (vis-à-vis non-bank sector)
(percentage share of securities in total assets)

	Stocks	Flows
1995	27.8	
1996	29.9	46.4
1997	32.5	46.1
1998*	34.7	68.1

* At end-June.

Source: BIS, International Banking Statistics.

2.1.2 The 1998 financial crisis

Beginning in the summer of 1997, the international financial markets were hit by successive waves of turbulence. In August 1998, what had appeared to be a regional crisis worsened and spread, becoming a global crisis that hit economies – principally exporters of raw materials – with characteristics and problems that were very different from those of the Asian countries. The Russian crisis, with the debt moratorium, had a sharp impact on other emerging economies through contagion effects, linked to fears of additional moratoriums on foreign debt servicing.

The sudden and violent fluctuations in the prices of financial assets (exchange rates, bond and share prices in emerging economies and industrial countries) recorded in the period signalled massive movements of international bank and non-bank capital that had few precedents in terms of the volumes traded, the range of financial instruments used and the countries involved.

---

3 This trend has already been observed for a considerable period of time in domestic banking in many industrial nations, but it is a relatively recent phenomenon in international banking and it could have negative side effects, such as: (i) an increase in the instability of financial markets, since the stabilising role played by banks, whose "customer relations" make them less inclined to follow behaviour dictated by panic, will have diminished importance; (ii) a reduction in the effectiveness of monetary policy, owing to the weakening of the traditional channels through which it operates.

During the first phase of the crisis, capital flowed out of the crisis-stricken Asian economies towards the industrial countries (the three largest benefited in virtually equal measure), but also towards Latin America and eastern Europe. One indication of this was the sharp rise in stock and bond prices in the OECD countries, in the presence of broadly stable exchange rates.

With the intensification and the spread of the crisis in August 1998, financial asset prices reflected a generalised outflow of capital from the emerging economies, this time including Latin America and eastern Europe, as well as the industrial countries that export raw materials (Norway, Australia, etc.), towards the industrial countries, with borrowers with the highest credit standing benefiting most (flight to quality). In this second phase of the crisis, the relative stability of exchange rates among the three large industrialised areas (the slight depreciation of the dollar mainly reflected changing expectations for US monetary policy) suggest that the capital flows were divided fairly equally between them.

It is widely believed that the closing-out of international arbitrage positions that were taken in the preceding three-year period played an important role in the 1998 financial crisis. After international investors (typically hedge funds, see Eichengreen and Mathieson (1998)) made large profits by raising funds in yen and reinvesting in emerging markets between 1995 and 1997, the sudden unwinding of these positions in 1998 appeared to have contributed to the amplification and propagation of the crisis (see BIS (1999); IMF (1998)). There is ample empirical evidence on this phenomenon, although precise estimates of the volumes of funds involved are not available. This is partly because investors could borrow yen not only on the spot market (e.g. on the interbank market, for which data are available; see next section), but also with forward instruments and derivatives (for example, forward exchange rates, futures, swaps and options), for which equally complete data sets are not available (see Garber (1998)).

Below, this hypothesis will be tested utilising data on bank capital flows, paying particular attention to the role of Japanese and offshore centre banks (which are respectively the principal “creators” and “reallocators” of international liquidity) and to non-bank agents located in offshore centres, which presumably include some hedge funds and other non-bank financial intermediaries.

2.2 Bank capital flows between large areas

BIS statistics on international banking activity make it possible to track the movements of bank capital between the main geographical areas in recent years. It is important to note that the data on bank assets and liabilities are available with greater detail only for the 24 reporting countries. For the rest of the world, especially the emerging economies, information is only available to the extent that these countries have relations with banks in the reporting countries; hence data on bank relations between emerging economies are not included (for example, there are no data on the large movements of bank capital which reportedly took place between banks in Korea and Thailand at the beginning of the Asian crisis).

Charts 2 and 3 offer an overview of gross capital flows (adjusted by the BIS for exchange rate changes) initiated by banks located in a number of countries and geographical areas. The arrows indicate the direction of flows, i.e. of changes in gross assets of a country or an area with respect to the counterpart (in the case of interbank flows the arrows can also be read, in the opposite direction, as changes in liabilities). Where appropriate, the figures inside the squares show capital flows within the economic area considered (for example, between OECD countries or between offshore countries). By construction, if one added up all flows reported in Charts 2 and 3 (between areas and intra-area), one would obtain the totals given in Chart 1. The periods considered correspond to the three above mentioned cycles: 1991–94; 1995–97 and 1998. The last is divided into two sub-periods (first half and third quarter), owing to the different nature of the two phases of the crisis.

Chart 2a
Flows of interbank loans (adjusted for exchange rate changes)
(changes in gross assets and, in brackets, net assets; billions of dollars)

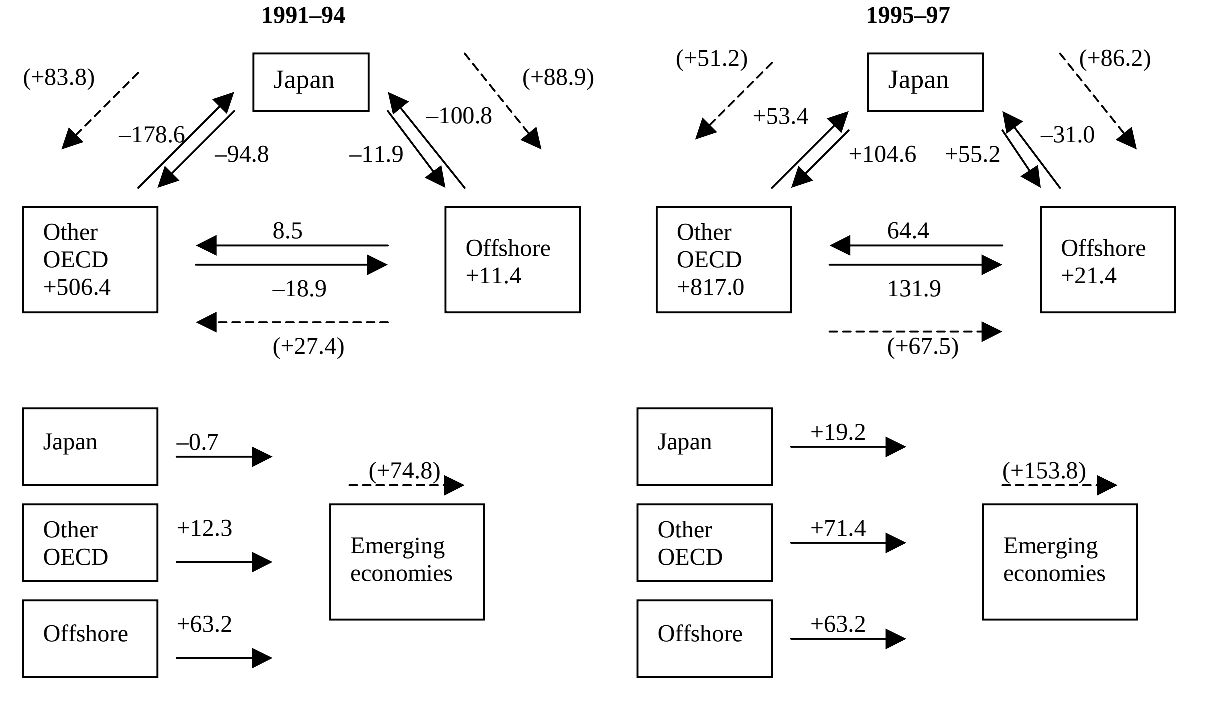
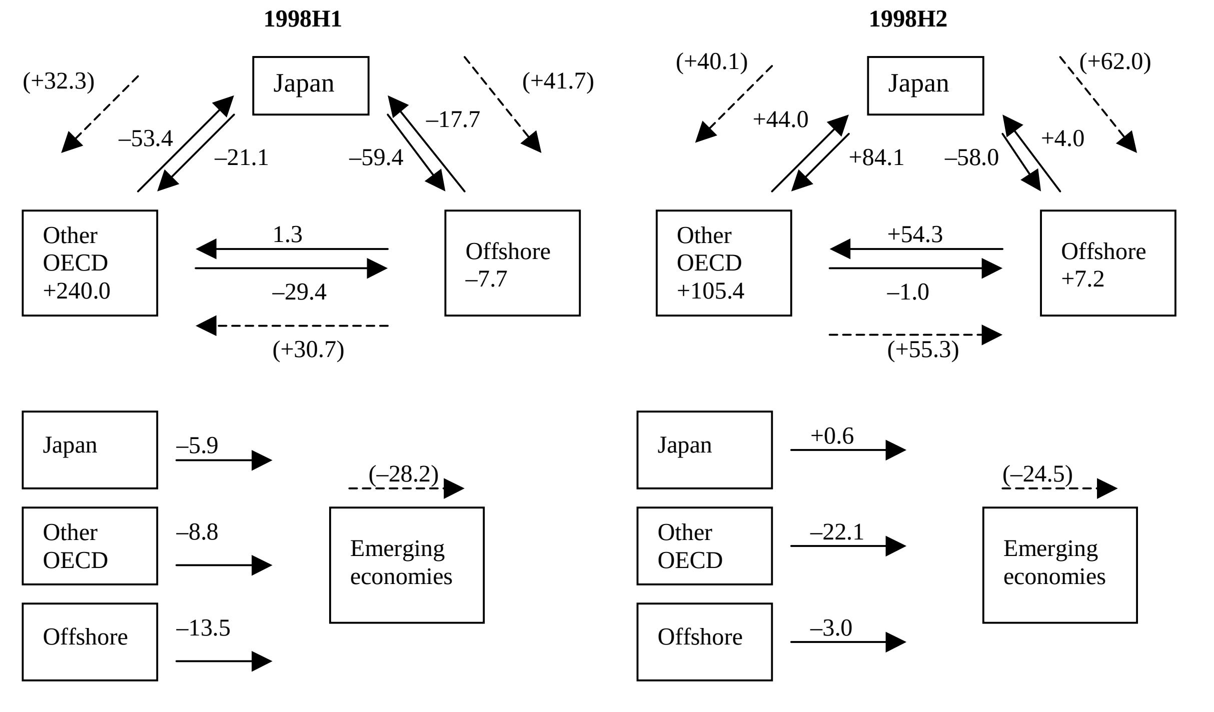


Chart 2b
Flows of interbank loans (adjusted for exchange rate changes)
(changes in gross assets and, in brackets, net assets; billions of dollars)



Source: BIS.

Chart 3a
Flows of bank loans to non-bank sector
(changes in gross assets adjusted for exchange rate changes; billions of dollars)

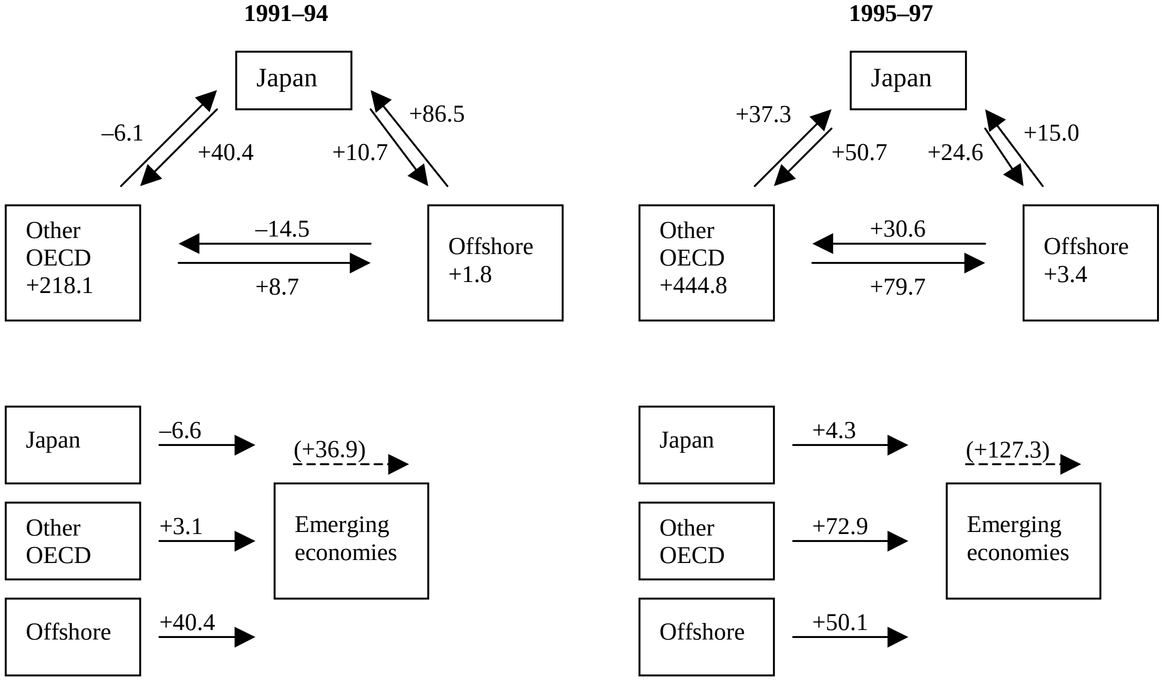
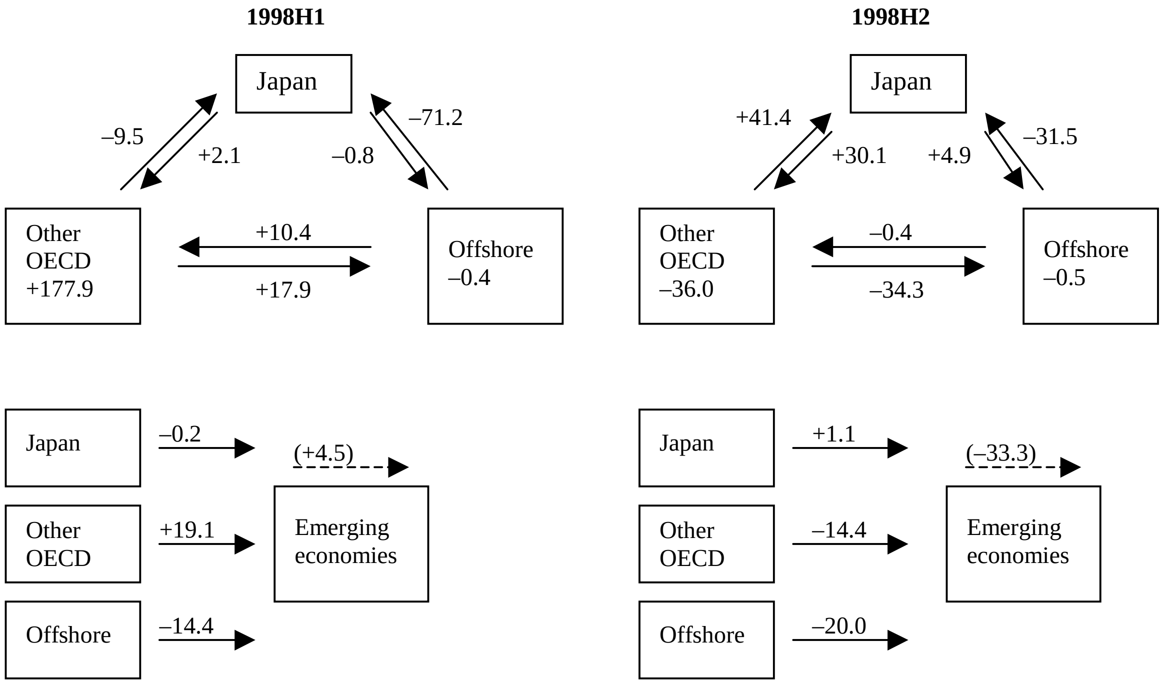


Chart 3b
Flows of bank loans to non-bank sector
(changes in gross assets adjusted for exchange rate changes; billions of dollars)



Source: BIS.

The top part of the charts refers to the reporting area only, indicating movements *between* reporting countries or areas (whose amount is given by the figures next to the arrows) and *within* reporting areas (figures inside the squares):

- Japan;
- other reporting industrial countries (henceforth "other OECD"): the United States, Canada, EU members (excluding Portugal and Greece), Switzerland and Norway;
- offshore centres: Hong Kong, Singapore, the Cayman Islands, the Bahamas and other minor centres.

The lower part of the charts describes the relations between the reporting area and a group of non-reporting countries labelled as "emerging economies": these include all Asia (excluding Japan, Hong Kong and Singapore), Latin America and central and eastern Europe.

2.2.1 Interbank capital movements

With reference to interbank flows (see Charts 2a and 2b), in the years 1991 to 1994 inside the reporting area there was a generalised withdrawal of funds between the three areas considered (close to \$400 billion), in part owing to the retrenchment of cross-border activity by the banks operating in Japan. The latter reduced their gross lending to the rest of the OECD area by nearly \$100 billion and their gross borrowing by around \$180 billion, and reduced their liabilities to offshore centres by more than \$100 billion. Reflecting the excess of saving over domestic investment, in the same period net capital outflows from Japan amounted to around \$170 billion (i.e. resident banks' net external creditor position increased by this amount). As to capital movements with countries outside the reporting area, i.e. with banks in the emerging economies, there was a substantial flow of funds towards the latter (\$75 billion) effected almost entirely by the offshore centres. At the global level, during the period in question banks in the offshore centres acted as international "reallocators" of funds; they were net borrowers from Japan in the order of \$90 billion and net lenders of a virtually identical amount to the OECD area (\$27 billion) and the emerging economies (\$63 billion).

In the three years 1995–97, characterised by strong growth in international banking activity, inside the reporting area more than \$400 billion of gross loans were granted across the three blocs. Japanese banks granted new gross loans in large amounts to the rest of the OECD area (\$105 billion) and to offshore centres (\$55 billion);[4] the net capital outflow from Japan was also large (\$137 billion), although slightly lower than that recorded in the previous period. Within the reporting area a reallocative function was performed by the banks of the OECD area, which effected net funding in Japan (\$50 billion) and net lending to the offshore centres (\$65 billion). This development, in some respects surprising, seems to imply an assumption of risk by OECD area banks resulting from a maturity and/or currency transformation in intermediation between the other two areas.[5]

As to business with countries outside the reporting area, in 1995–97 the reporting countries (mainly the OECD countries and the offshore centres, in nearly equal measure) transferred some \$150 billion to banks in emerging economies. Combining the information on cross-border activity inside and outside the area, at the global level it was again the banks in offshore centres that reallocated interbank funds with net fund-raising of around \$150 billion from "other OECD" countries and Japan, and net lending of \$63 billion to the emerging economies. It is worth noting that in terms of net flows, at a global interbank level, offshore centres were net borrowers for almost \$90 billion: as will be seen below, part of this net funding was probably used to finance non-bank customers.

---

4 It should be borne in mind that these figures refer to the residence of the intermediaries, regardless of the nationality of the parent bank. As is detailed below, some of the interbank movements from Japan to offshore centres were actually transactions between parent banks and branches operating abroad.

5 The BIS statistics are consistent with the hypothesis that in 1995–97 the banks of "other OECD" countries performed currency transformation: around 70% of the funds they raised from banks in Japan were in yen, while around 60% of the loans they granted to banks in offshore centres were in their own national currencies.

In 1998 the outbreak of the Asian crisis and, from August, its spread to other emerging economies caused a virtually across-the-board cutback in cross-border interbank gross lending in the first half of the year, which was followed by a rebound of gross lending in the second half. In terms of net flows, inside the reporting area both halves of the year witnessed large net outflows of capital from offshore banks to the other two areas (totalling roughly \$190 billion); the repatriation of offshore capital to Japan (more than \$100 billion net in 1998) is consistent with the hypothesis of de-leveraging. Outside the reporting area, Japan's banks reduced their lending to banks in the emerging economies by more than \$50 billion.

2.2.2 Capital flows to non-bank customers

BIS statistics also allow tracking of cross-border bank capital movements in respect of non-bank counterparts (see Charts 3a and 3b), even though the definition of the non-bank sector is not uniform across countries and in some cases may include financial intermediaries such as hedge funds.

Inside the reporting area, in the four years 1991–94 the contraction in interbank activity was not accompanied by one in business with non-bank customers, which is traditionally more stable. Capital flows to the non-bank sector were positive in sign, albeit for relatively small amounts (more than \$150 billion of gross loans were granted); exceptions were the large loans from offshore banks to Japanese non-banks, totalling \$87 billion, and from Japanese banks to North American and European companies, amounting to \$40 billion. Outside the area, there were substantial flows of nearly \$40 billion from reporting area banks to non-banks in the emerging economies, perhaps compensating for the lower level of demand from the industrial countries during a period of cyclical weakness. Globally, in the same four years offshore banks were the largest lenders to the non-bank sector (for a total, net of redemptions, of more than \$110 billion); since offshore banks' net interbank fund-raising was virtually nil (see the previous section), their net creditor position increased significantly.

In the period between 1995 and 1997 there was a generalised increase in international lending to non-banks. Inside the reporting area capital flowed across the three areas concerned; the largest flows were those from Japanese banks to non-bank borrowers in "other OECD" (\$51 billion) and from banks in "other OECD" to non-banks in offshore centres (\$80 billion). Together with the inflow of capital from banks in Japan (\$25 billion), the latter brought the total inflow to the non-bank sector of the offshore centres to more than \$100 billion; considering the relatively modest GDP of those countries, it is common opinion (see BIS (1999)) that part of this borrowing was carried out by hedge funds located in those countries, where they are registered as non-banks. Outside the circuit of reporting countries, there were movements of nearly \$130 billion from reporting banks to firms in the emerging economies; adding up these to the above mentioned interbank flows, total capital flows to the emerging economies amounted to around \$280 billion.[6] It is also worth emphasising that, globally, lending by offshore banks to foreign non-banks totalled around \$95 billion, which is roughly the net borrowing by offshore centre banks in the interbank market (see above).

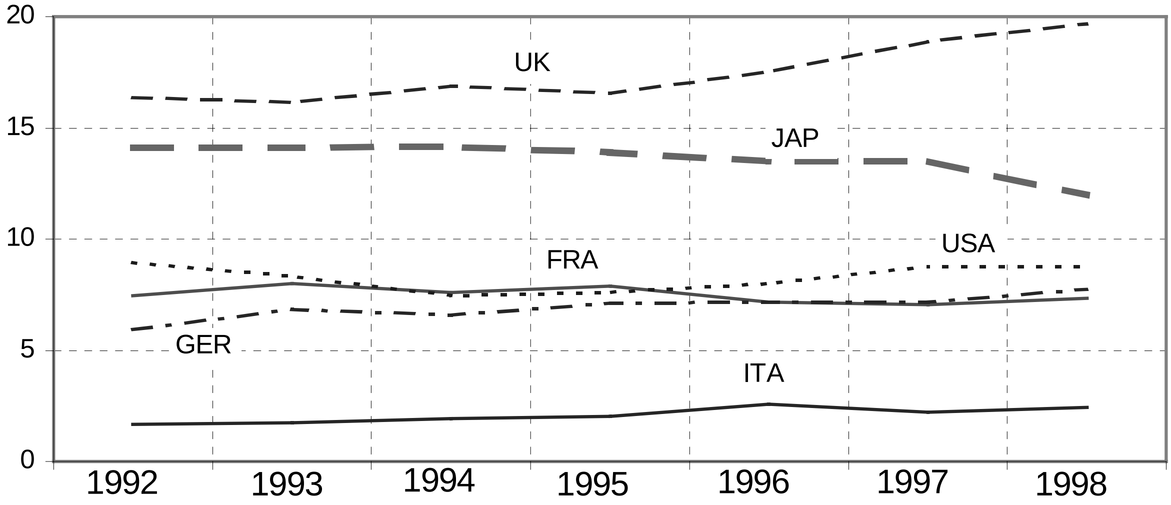
With the outbreak of the international financial crisis, in 1998 there was a slowdown in the flow of bank credit to foreign firms, but not a generalised contraction in lending. In the first half of the year there were positive flows both within the reporting area (e.g. between "other OECD" and offshore centres) and in activity external to it ("other OECD" provided nearly \$20 billion to the emerging economies, diverting funds from Asia to Latin America). In the second half of 1998, with the spread of the crisis, there were further positive flows of credit within the reporting area, while loans to the emerging economies from all three reporting area blocs contracted by around \$33 billion. It is worth noting that in 1998 banks in the offshore centres drastically curtailed their lending to non-banks in Japan by around \$100 billion and in the emerging economies by around \$34 billion.

[6] In order to measure the total inflow of resources to emerging economies, in addition to banks one would need to consider capital transferred by private investors, e.g. purchases of bonds and shares, and by public organisations.

2.2.3 *Capital flows between parent banks and foreign branches (international banking statistics by "nationality"): the case of Japanese banks*

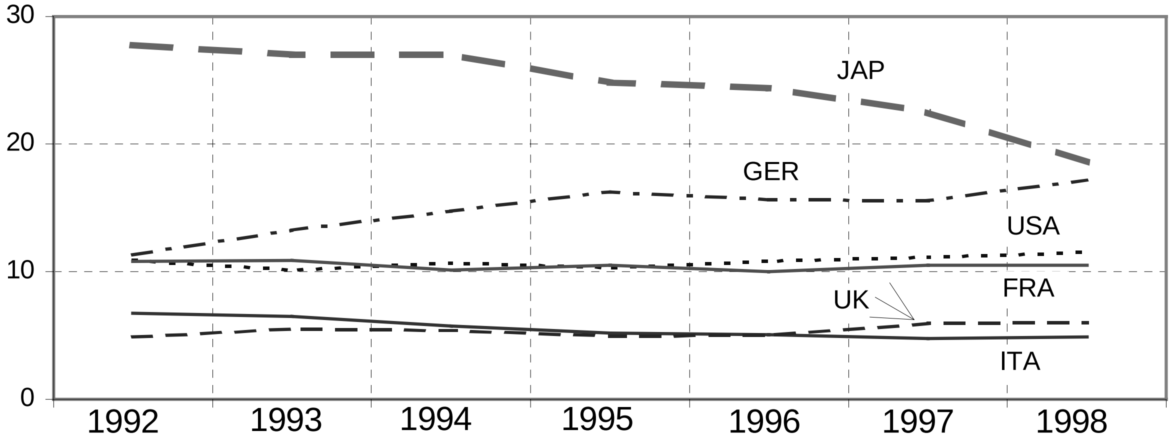
The data on international banking activity used above are based on the concept of *residence* of intermediaries. The BIS also collects and elaborates statistics based on banks' *nationality*, by consolidating data collected in all reporting countries, and provides a breakdown by counterpart (with three categories: branches of the same group, other banks and non-banks) and by currency of denomination.

Chart 4
External assets of reporting banks (with all sectors) ***by residence***
(percentage share of total)



Source: BIS, International Banking Statistics. End-period data (1998: June).

Chart 5
External assets of reporting banks (with all sectors) ***by nationality***
(percentage share of total)



Source: BIS, International Banking Statistics. End-period data (1998: June).

The statistics based on nationality provide important additional information with respect to those based on residence particularly for countries where there is a large presence of foreign intermediaries (e.g. the United Kingdom) or, conversely, whose banks have a large presence abroad (e.g. Japan). In the latter case, the quantification of intragroup funds transfers yields indications about the strategy pursued by a given banking system. This section takes a closer look at the behaviour of the Japanese banking system in the past few years, first considering Japanese banks' market shares and then examining their intragroup capital flows in the world.

Charts 4 and 5 show the gross external assets of the banks of each of the six leading industrial countries as a percentage of the total for all reporting countries (the sum of the six shares is therefore less than 100). While the market share of banks resident in Japan decreased from 14% to 12% between 1992 and 1998, mainly to the benefit of the United Kingdom and Germany, the market share of banks of Japanese nationality (i.e. including branches abroad) fell much more markedly, from 28% to around 18%, primarily to the benefit of German banks, whose market share grew from 11% to 18% and is now nearly equal to that of Japanese institutions. This redistribution of market shares, which gained pace in 1997 and 1998, is attributable to the crisis that has been plaguing the oversized and undercapitalised Japanese banking system since the start of the 1990s and to the policies of expansion and globalisation pursued in recent years by European and, above all, German banks (see BIS (1998)).

Charts 6a and 6b show the capital movements (changes in gross assets) effected by Japanese banks in the three periods examined earlier, broken down by counterpart.[7]

In the four years from 1991 to 1994 the significant contraction in the balance sheets of banks resident in Japan was paralleled by one in those of banks of Japanese nationality engaged in cross-border business. The latter's repayments of liabilities were mainly to other banks ($455 billion), whereas the reduction in their assets involved both claims on other branches of the group and claims on other banks ($227 billion and $354 billion respectively); activity with non-bank customers kept growing, with banks of Japanese nationality granting $140 billion of fresh funds.

The striking feature of the period 1995–97 is represented by the sharp reduction of lending by *Japanese banks* to non-bank borrowers by $207 billion; in comparison, in the same period transactions carried out by banks *located in Japan* with non-bank agents were much smaller in size (see Chart 3a). This fact is consistent with the anecdotal evidence according to which a division of labour exists between Japanese parent banks and foreign branches, with the former specialising in supplying funds to the latter (which are typically located in offshore centres) rather than directly to non-bank customers, and the foreign branches in disbursing loans to non-resident non-banks (typically located in Japan), with a sort of "rechannelling" of funds from banks located in Japan to their foreign branches and then back to Japanese firms.

A sharp contraction in activity in the first half of 1998 was followed by a relative stabilisation in the second half. The shrinking of balance sheets in the first half was not unlike that recorded at the start of the decade, i.e. Japanese banks sharply reduced both liabilities and assets principally in respect of banks (more heavily outside the group than vis-à-vis same-group branches); non-bank counterparts were spared this downsizing, with lending and borrowing increasing by around $20 and $90 billion, respectively. In the second half of 1998 the changes were smaller, and Japanese banks raised significantly their lending and borrowing with related offices while reducing or limiting it vis-à-vis other banks and non-banks.

[7] These data cannot be compared with those examined in the previous section (Charts 2 and 3) because they are based on the concept of bank nationality, not of bank location.

Chart 6a
Lending by Japanese banks to non-residents
(exchange rate adjusted changes in gross stocks; billions of dollars)

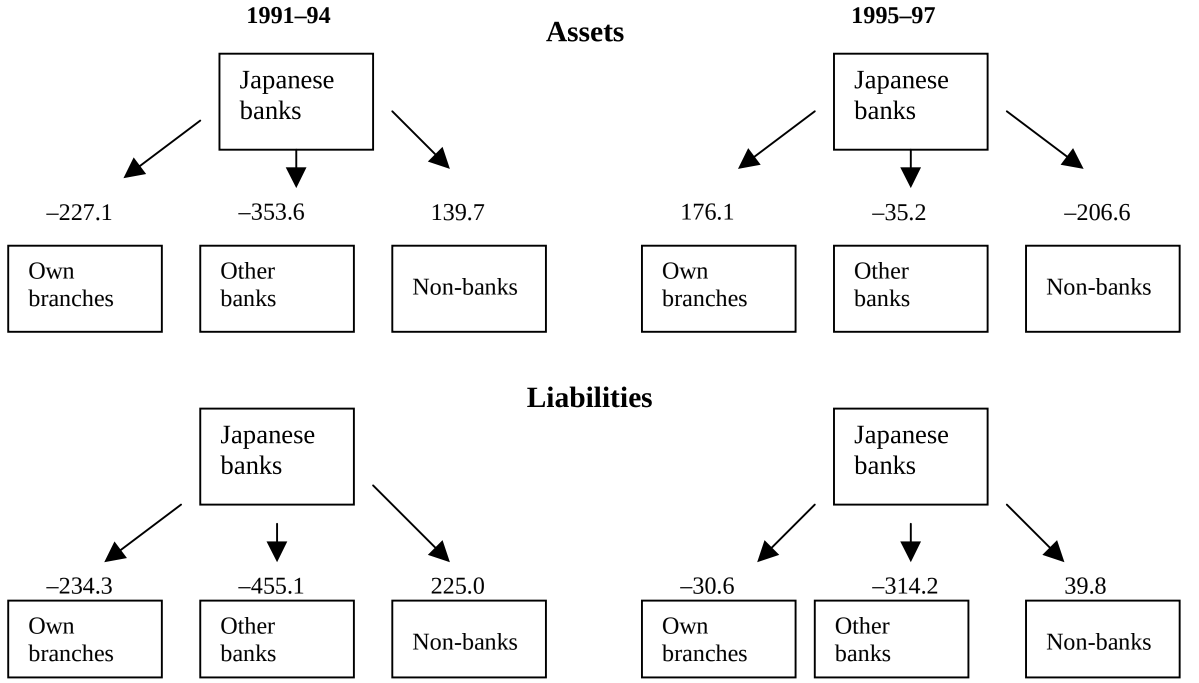
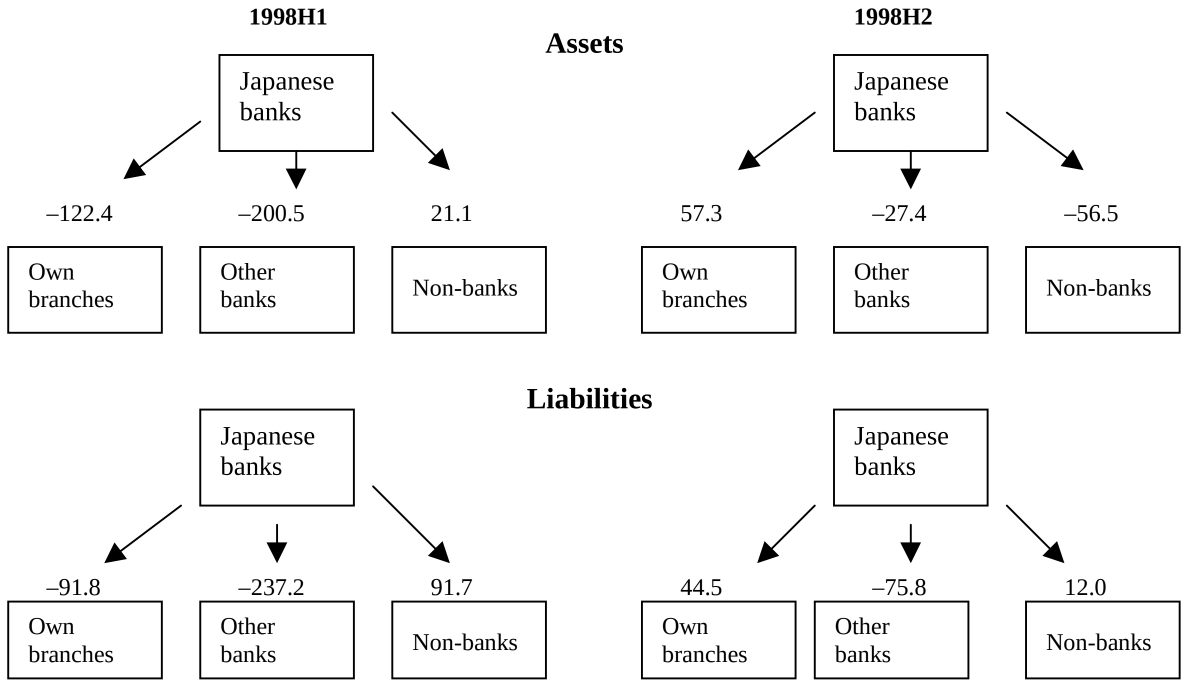


Chart 6b
Lending by Japanese banks to non-residents
(exchange rate adjusted changes in gross stocks; billions of dollars)



Source: BIS.

3. The determinants of international liquidity

3.1 Introduction

The literature analysing the development of international liquidity is extremely limited, particularly with regard to analysis of the geographical breakdown of cross-border flows. The most interesting contribution is that of Alworth and Andresen (1992), who examine the dynamics of cross-border deposits in the 1980s in connection with competition between financial centres. A first part of that study focuses on the development over time of cross-border deposits, classified according to the traditional criteria of residence of the bank and residence of the deposit holder. The data used in that work are supplemented in the present study with more recent statistics and shown in Tables 2 and 3. Table 2 shows the share held by each country's banking system in "hosting" cross-border deposits. As in the preceding years, the United Kingdom is the leading financial centre, with cross-border deposits at the end of September 1998 totalling around \$2,500 billion, equal to 21% of the total stock of deposits held with banks located in the reporting area. Shares approaching that of the United Kingdom were held by the reporting offshore centres considered together (the Bahamas, Bahrain, the Cayman Islands, Hong Kong, the Netherlands Antilles and Singapore). Over the 15 years considered, the share of deposits held with banks located in Germany rose from 2.7% to 9.7% and that held with banks resident in France from 5.7% to 7.1%, while that with banks in the United States diminished slightly from 12.9% to 10.8%. The end-of-period share held with banks located in Japan fell sharply from 12.5% to 6.0% from the peak recorded at the end of the 1980s.

Table 2

Cross-border deposits held with banks of individual reporting countries as a share of area's total (billions of dollars and percentages)

	End-December 1983			End-December 1990			End-December 1996			End-September 1998		
	Total (1)	Non-banks	% share (1)/(2)	Total (3)	Non-banks	% share (3)/(4)	Total (5)	Non-banks	% share (5)/(6)	Total (7)	Non-banks	% share (7)/(8)
AT	25.9	1.4	1.2	67.3	12.4	1.0	89.7	11.1	1.1	104.4	10.9	1.1
BE	72.6	8.5	3.4	217.3	36.4	3.4	266.4	70.9	3.3	278.6	82.3	2.9
LX	79.1	12.0	3.7	271.2	107.7	4.2	383.6	163.1	4.7	387.5	150.2	4.1
DK	5.1	0.4	0.2	43.8	2.5	0.6	38.8	7.7	0.5	278.6	9.9	3.0
SF	7.1	0.3	0.3	42.8	2.8	0.6	16.2	0.7	0.2	14.7	0.7	0.2
FR	138.7	15.1	6.5	482.1	46.9	7.5	617.0	56.3	7.6	712.0	61.7	7.6
DE	57.4	14.0	2.7	224.8	52.8	3.5	570.6	170.8	7.0	836.6	219.6	8.9
IE	5.0	2.5	0.2	17.8	5.6	0.3	64.2	18.3	0.8	128.3	38.8	1.4
IT	45.6	1.9	2.1	142.9	11.4	2.2	247.7	15.8	3.1	265.8	39.2	2.8
NL	55.5	12.1	2.6	148.0	42.7	2.3	217.9	55.5	2.7	331.6	60.8	3.5
NO	6.2	2.5	0.3	20.8	1.8	0.3	17.9	2.3	0.2	26.2	2.6	0.3
ES	18.5	8.4	0.9	64.0	26.7	1.0	128.0	43.4	1.6	189.2	52.1	2.0
SE	14.0	1.3	0.6	90.6	12.1	1.4	56.7	7.8	0.7	86.4	15.2	0.9
CH	117.5	90.0	5.5	312.7	217.0	4.9	404.0	242.6	4.9	509.2	261.3	5.4
UK	515.3	150.5	24.2	1,201.3	327.4	18.7	1,555.8	369.4	19.2	1,984.5	500.6	21.1
CA	62.2	25.1	2.9	81.0	35.9	1.3	98.8	36.7	1.2	120.0	36.5	1.3
JP	106.6	2.3	5.0	958.5	13.3	14.9	695.8	17.6	8.6	629.9	29.0	6.7
US	294.6	53.5	13.9	653.7	80.7	10.2	870.9	102.2	10.8	1,036.9	137.8	11.0
Off-shore	494.1	161.1	23.3	1,368.5	333.8	21.3	1,760.1	446.2	21.7	1,691.4	504.0	18.0
Total	2,121.0 (2)	562.9	100.0	6,409.1 (4)	1,369.9	100.0	8,100.1 (6)	1,838.3	100.0	9,390.6 (8)	1,506.0	100.0

Table 3
Area of origin of deposits held by non-banks with banks located in reporting area
(billions of dollars; figures for banks plus non-banks in brackets)

Area of origin of deposit	End-December 1983	End-December 1990	End-December 1996	End-September 1998
Reporting area	371.3	1,247.8	1,377.9 (6,296.7)	1,664.9 (7,266.9)
Non-reporting industrial countries	12.8	49.0	64.7 (187.7)	66.9 (202.6)
Offshore centres	–	–	285.0 (1,127.4)	378.0 (1,319.7)
of which:				
Cayman Islands	–	–	66.9 (321.4)	127.8 (405.9)
Singapore	–	–	13.6 (177.8)	16.6 (221.6)
Eastern Europe	0.6	1.9	8.7 (48.8)	11.8 (49.1)
Asia	17.4	44.1	81.4 (257.2)	107.3 (287.4)
Latin America	37.3	85.2	110.1 (228.2)	118.8 (238.3)
of which:				
Argentina	6.1	17.0	16.4 (26.6)	16.8 (35.3)
Brazil	7.0	17.5	16.2 (71.4)	17.7 (59.5)
Mexico	11.5	19.5	21.1 (37.8)	24.7 (47.4)

Table 3 shows the geographical origin of cross-border deposits held by non-banks with banks located in the reporting area (i.e. based on the residence of the depositor). It can be seen that most of the deposits originate from agents located within the reporting area: roughly three quarters of the total in the case of both bank and non-bank depositors. The other main areas of origin of the funds are the offshore centres among which the Cayman Islands accounts for around one third and Latin America. Reflecting this characteristic of the geographical distribution of cross-border deposits, in the econometric section more attention is devoted to analysing total deposits, which are largely held in the industrial countries, rather than to their distribution by geographical area (eastern Europe, offshore centres, Latin America).

3.2 The results of Alworth and Andresen

Alworth and Andresen (1992) identify a number of determinants of the behaviour of cross-border deposits. The reasons for depositing funds abroad include financing trade flows, investing in foreign financial assets and diversifying the default risk of one's domestic banking system. Obviously, the amount of deposits held (like the size of trade flows between two countries) should be strictly dependent on the wealth of the two countries, as approximated by GDP. Alongside these main factors, the authors also consider other characteristics of the country where funds are deposited, such as the reserve requirement, the existence of regulatory constraints on interest rate movements, the efficiency of the financial market and the financial and political riskiness of the country.

The econometric investigation conducted by the authors analyses a cross section of deposits classified according to the residence of the deposit holder. The dependent variable is the logarithm of deposits (expressed in billions of dollars) held by non-bank residents in country *i* with banks located in country *j*. The explanatory variables are:

- the output of the two countries (*i*, *j*), whose coefficients should be positive (GDP);
- the level of bilateral trade between the two countries (BITR), whose sign is expected to be positive;
- the ratio of stock market capitalisation to output (CAP/GDP), whose sign is expected to be positive;
- stock market turnover (TURN), whose sign is expected to be positive;
- the differential between the reserve ratio in the two countries (RR1–RR2), whose sign is expected to be negative;
- the level of taxation (WT);
- the level of banking secrecy (BSECR);
- the rating of the financial centre in which the deposits are held (RAT);
- the degree of specialisation of the financial centres, i.e. the fact that some are mainly involved in fund-raising, others in lending, as measured by the ratio between deposits held in the country by non-banks and those held by banks (RATC).

The equations were estimated on the basis of end-year data for 1983, 1986 and 1990. A summary of the results is given in Table 4.

Table 4
Summary of results

	1983	1986	1990
Specialisation (RATC)	–3.1057	–3.5429	–3.4216
Trade (BITR)	1.1278	1.2078	0.4438
GDP1	0.0024*	0.0047	0.0076
CAP/GDP2	0.0019*	0.0066	0.0072
RATING (RAT)	0.0048*	0.0023*	0.0050*
Reserves requirement, country 1 (RR1)	0.0133*	–0.0110*	–0.0931
Reserves requirement, country 2 (RR2)	–0.0916*	–0.0545*	–0.0907
Secrecy (BSECR)	0.4793	1.5869	0.9071
R^2	0.4194	0.5075	0.5546

* Not significant at the 5% level.

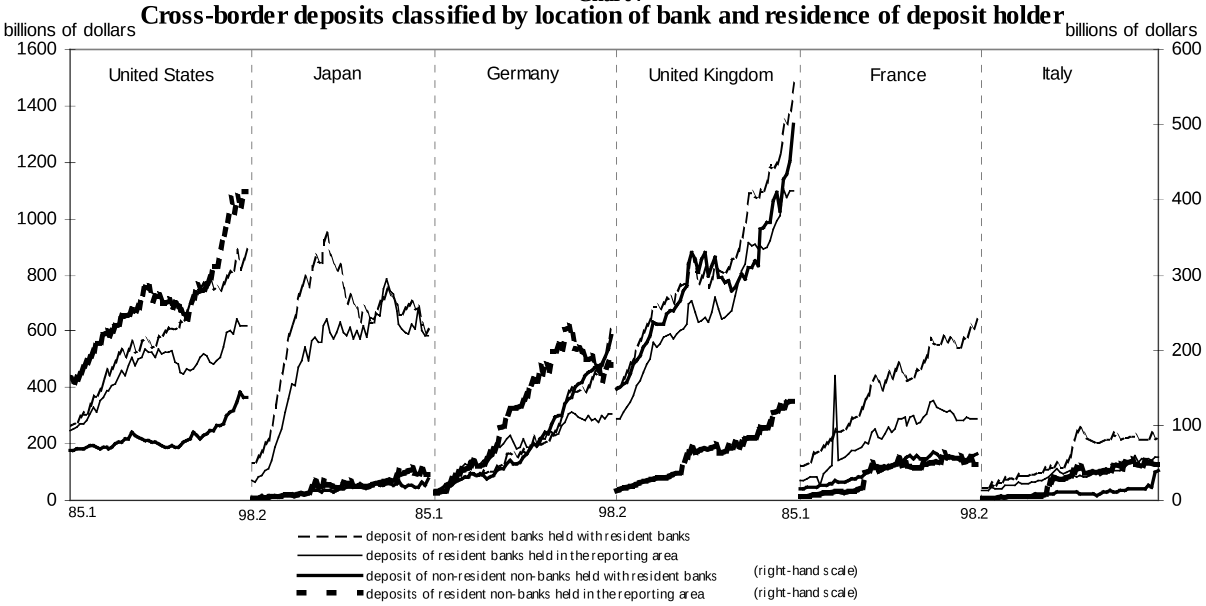
The R-squared of the regressions, which range between 42% for 1983 and 55% for 1990, are fairly high, especially considering the fact that the set of countries included in the study is heterogeneous (deposits held by non-bank residents of 17 countries with banks from 23 reporting countries). All of the main variables have the expected sign: domestic output is positively correlated with deposits, as are the ratio between market capitalisation in the bank's country of residence and the GDP of the deposit holder's country of residence and the size of bilateral trade flows. The other variables also have the expected sign: the level of banking secrecy has a positive sign and the RATC variable (ratio of non-bank deposits to interbank deposits) is negative, and can be interpreted as a scale variable, such that financial centres where interbank loans predominate attract more deposits from non-bank non-residents.

3.3 New econometric evidence

The econometric analysis conducted in this paper differs from the Alworth-Andresen study in that it examines a panel of data rather than a cross section. In addition, the range of cross-border deposits considered is broader in that it includes four categories of deposits: equations were estimated (over the period between the first quarter of 1985 and the second quarter of 1998) not only for cross-border deposits defined according to the *residence of the holder* (e.g. deposits held abroad by bank and non-bank residents of the United States) but also for deposits defined according to the *location of the issuer or "host"* (e.g. deposits held with US-located banks by both banks and non-banks located abroad).

The time profile of the four variables being estimated is shown in Chart 7. As noted in our discussion of Table 2, the United Kingdom is still the world's leading financial centre in terms of cross-border *deposits held with its banking system*: at the end of the second quarter of 1998, British banks held about \$1.5 trillion in deposits by non-resident banks and non-banks. US banks held about \$900 billion and Japanese banks \$600 billion, sharply down from their peak of nearly \$900 billion at the end of the 1980s. As regards the classification of deposits *by residence of the holder*, British banks held about \$1.1 trillion abroad, compared with \$600 billion by US and Japanese banks. Among non-bank deposit holders, US depositors held the largest amount of funds abroad, about \$420 billion, compared with \$200 billion by non-bank residents of Germany and \$150 billion in the United Kingdom. The rates of growth of the above aggregates were very high, especially in the United Kingdom, the United States and Japan: over the period, deposits held by bank and non-bank non-residents with resident banks grew by 120% and 180%, respectively, in the United States, 270% and 700% in the United Kingdom and about 670% and 700% in Japan.

Chart 7
Cross-border deposits classified by location of bank and residence of deposit holder



Charts 8a–d show the logarithms of cross-border deposits held by non-banks with banks in each of the G6 countries in relation to a selection of key variables: domestic and foreign GDP; short- and long-term interest rate differentials; the volume of bilateral trade; the stock of securities issued by the country's private and public sectors; the ratio of stock market capitalisation to output; and stock market turnover in the country in which the bank is located. In Charts 9a–d, the exercise is repeated for interbank deposits held by non-resident banks with banks in the G6 countries.

Deposits with banks in the G6 countries grew more rapidly than both domestic and foreign GDP in the United States (Chart 8a); in the other five countries the rates of growth in deposits and output do not differ excessively, especially in the most recent period. Interbank deposits by non-residents in the G6

Chart 8a

Cross-border deposits in relation to a selection of key variables

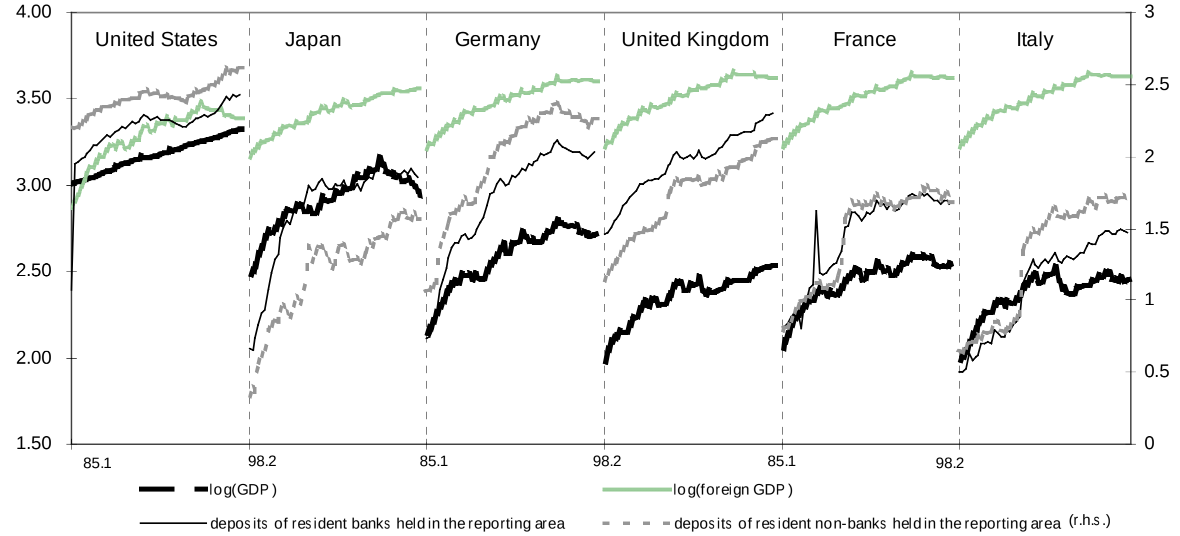


Chart 8b

Cross-border deposits in relation to a selection of key variables (cont.)

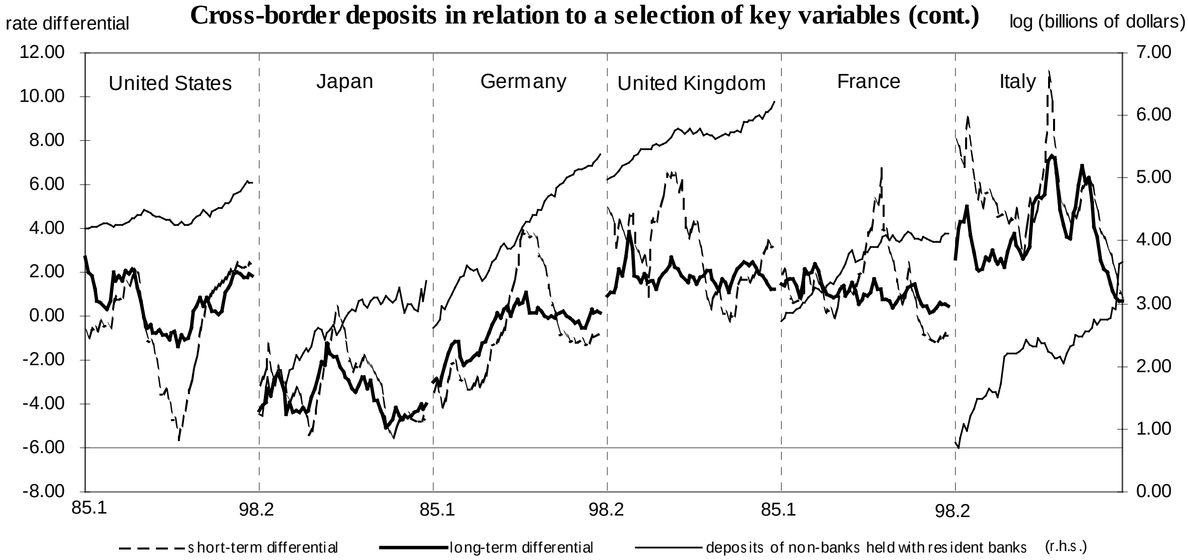


Chart 8c

Cross-border deposits in relation to a selection of key variables (cont.)

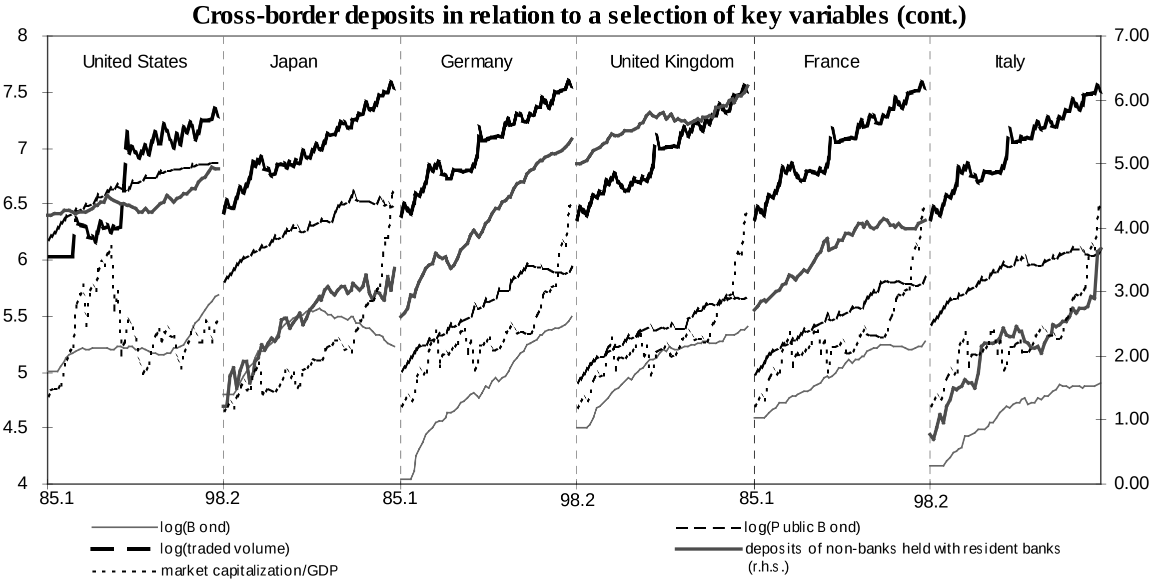
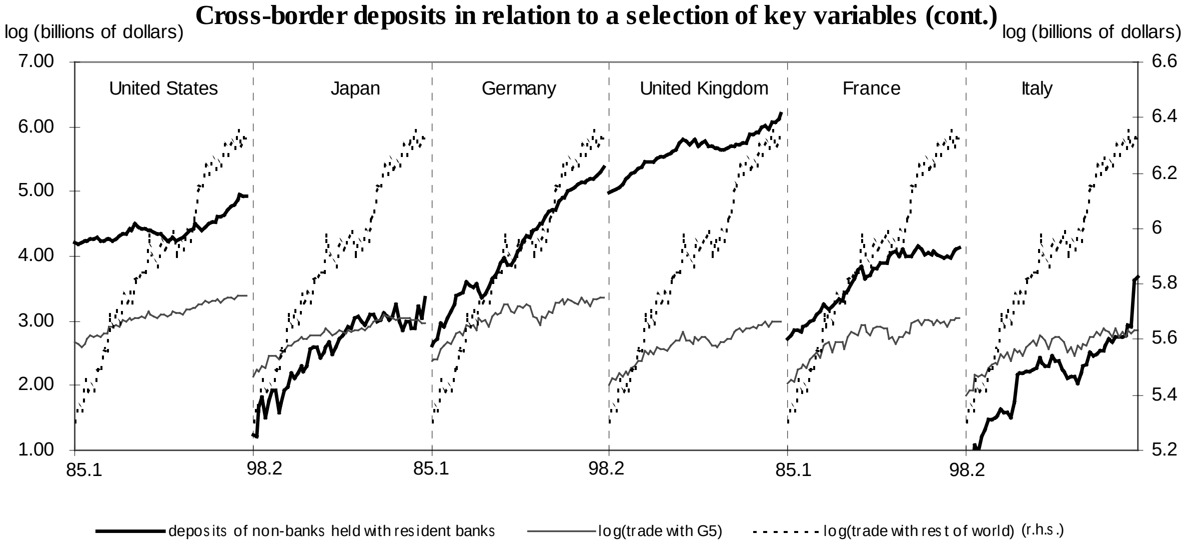


Chart 8d

Cross-border deposits in relation to a selection of key variables (cont.)



countries show much faster growth than GDP from the end of the 1980s, when the globalisation of markets began to accelerate (Chart 9a). Only Japan, where deposits grew very rapidly during the 1980s, recorded a sharp reversal of trend after the speculative bubble burst.

The link between the variables that measure the "financialisation" of the economy and the growth of deposits is especially evident in Charts 8c and 9c, where they are shown together with the logarithm of private and public sector securities, the ratio of market capitalisation to GDP and stock market trading volume. All these variables display high rates of growth during the 1990s, and those for stock market capitalisation are even higher than those recorded by deposits, which contributes to explaining their rapid expansion.

Chart 9a

Interbank deposits in relation to a selection of key variables

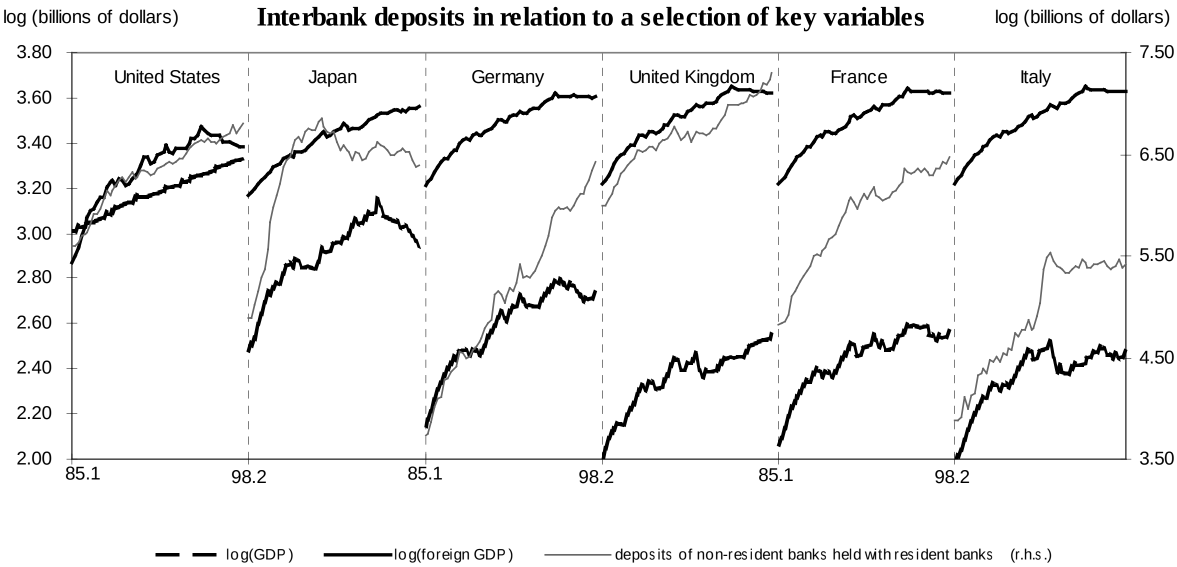


Chart 9b

Interbank deposits in relation to a selection of key variables (cont.)

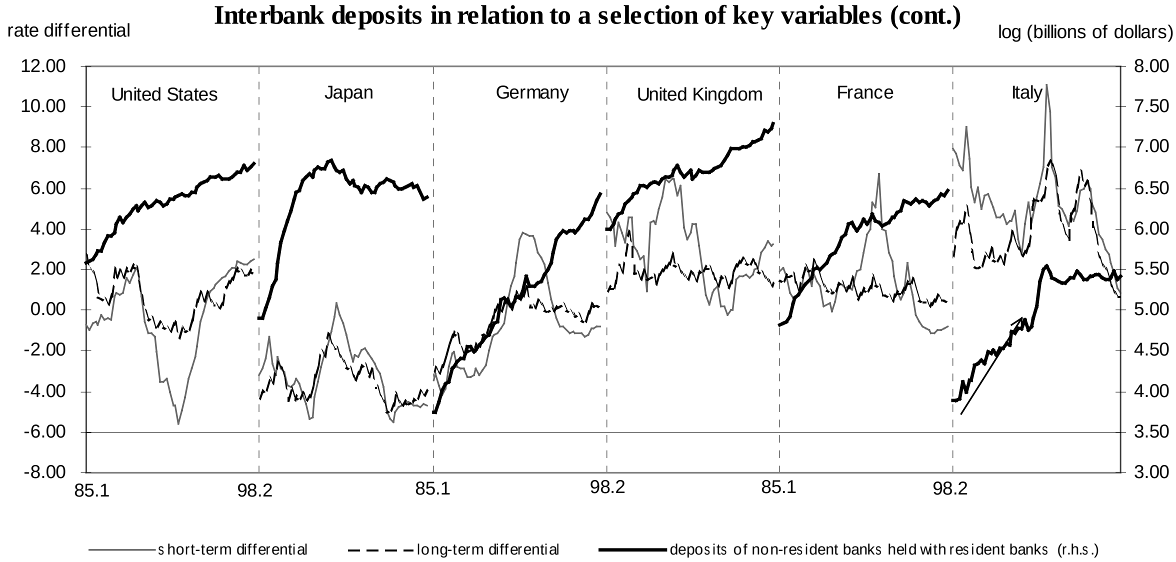


Chart 9c

Interbank deposits in relation to a selection of key variables (cont.)

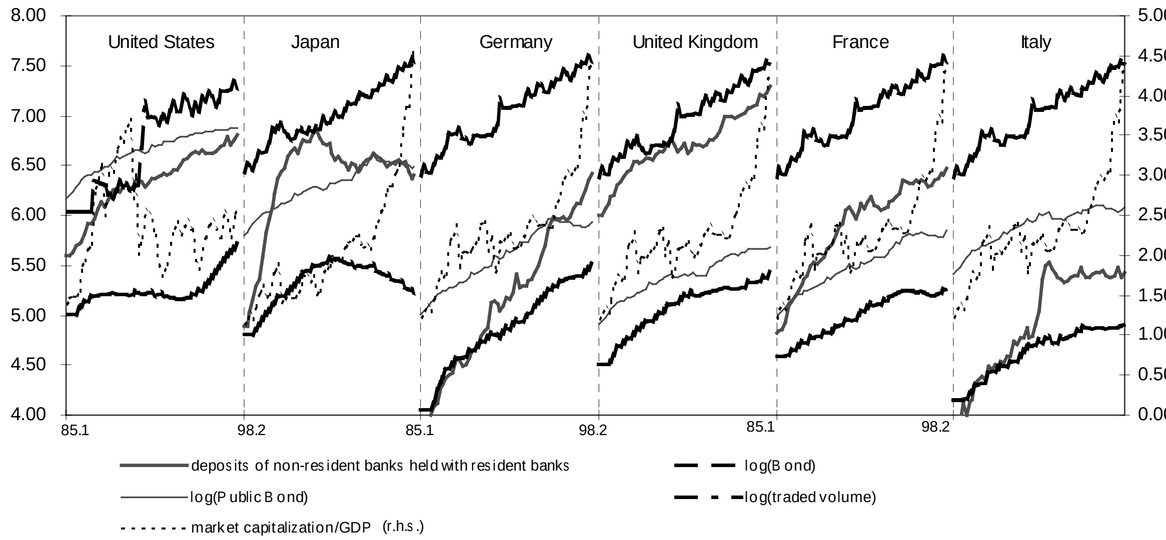
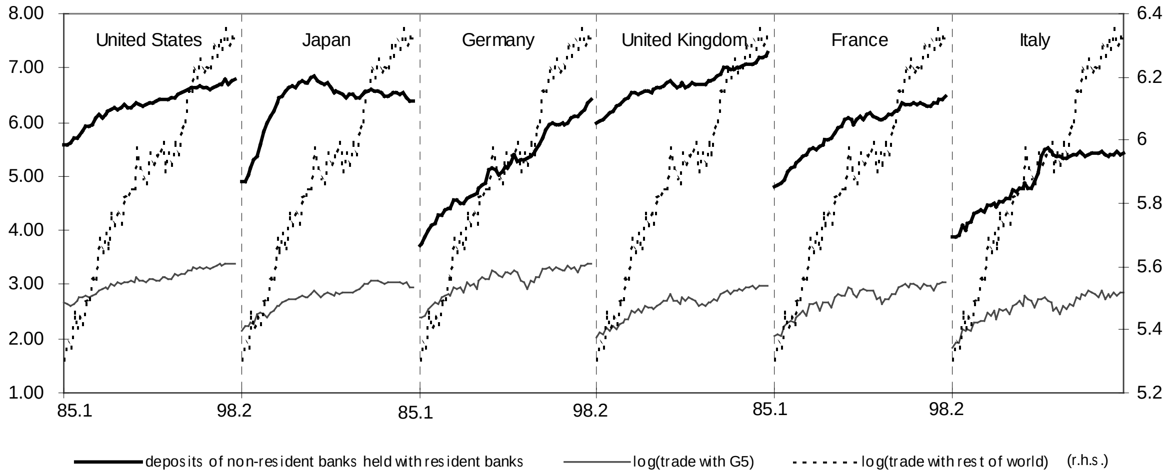


Chart 9d

Interbank deposits in relation to a selection of key variables (cont.)



If the regressions should confirm that cross-border deposits are more closely linked to financial variables than to macroeconomic determinants, we would be able to argue for a *financial view* of the growth of deposits. This position also finds support in a branch of the literature that in the last 10 years has focused on the so-called microstructure of financial markets and on the development of derivatives markets. The results obtained by this literature are based on direct observation of the foreign exchange market, the broadest and most active in the world. Trading volumes on this market are enormous because individual participants carry out repeated transactions to achieve a desired level of risk for their portfolio, selling foreign exchange forward for each asset position and buying foreign exchange forward for each liability position. Such behaviour sharply amplifies the original transaction volume, consistently with so-called "hot potato" models of risk sharing. According to such models, banks expand their original asset and liability positions with final investors on their balance sheets with positions taken with other intermediaries to achieve the desired risk-return combination for their portfolio.

Tables 5–7 show the results of the regressions performed on the deposits of banks and non-banks classified by residence of the bank and residence of the deposit holder. The estimates are in cross-section form for three periods: 1986Q2, 1990Q2 and 1998Q2. The equations were subsequently reestimated in time series form for the individual countries of the G6 and in panel form for the G6 as a whole; in all these cases, the sample period goes from the first quarter of 1985 to the second quarter of 1998.

Table 5
Cross-section estimate at 1986Q2

Explanatory variables	Non-bank sector deposits held by G6	Banking sector deposits held by G6	Non-bank sector deposits held by G6 in reporting area	Banking sector deposits held by G6 in reporting area
Domestic GDP	0.360*	1.620	0.377	0.480*
Foreign GDP	–0.496*	–1.660	0.840	4.320
Inflation difference	–0.026*	–0.025	0.0024*	0.013
Short-term rate difference	0.014	0.037	–0.0054**	–0.042*
Long-term rate difference	0.012*	–0.0073	–0.0112*	0.0122*
Trade with G5	1.050	1.050	0.089	0.0856*
World trade	0.180*	0.976	0.370	–1.090
Trade with world	–3.400	–4.150	–1.630	–6.970
G5 trade	1.580	0.130*	–0.086*	7.320
Capitalisation/domestic GDP	0.077	0.078	–0.018*	–0.134
Capitalisation/foreign GDP	–0.115	–0.103**	0.144	–0.293
Stock market volatility difference	0.006*	–0.025*	0.053	–0.052**
Exchange rate volatility difference	0.092	0.011	0.042**	0.017
Stock of private securities	0.565	0.811	0.029*	–0.019
Stock of public securities	1.080	0.813	–0.207**	0.611**
Trading volume in stock market	0.022	0.061	–0.047*	–0.559
Interbank/bank deposits in G6	0.010	–0.012	0*	–0.010*
Interbank/bank deposits in area	0.108	0.093	0.223	0.101
R^2	0.95	0.94	0.83	0.55
DW	0.37	0.45	0.57	1.70

* Not significant at the 5% level. ** Not significant at the 10% level.

The explanatory variables are:

- the GDP of country *i*;

- the GDP of the group of countries excluding *i*;
- the inflation differential between country *i* and the group of countries excluding *i*;
- the short-term interest rate differential between country *i* and the group of countries excluding *i*;
- the long-term interest rate differential between country *i* and the group of countries excluding *i*;
- the sum of exports and imports of country *i* with the group of countries excluding *i*;
- the sum of world exports and imports;
- the sum of exports and imports of the group of countries excluding *i*;
- the ratio of stock market capitalisation to the GDP of country *i*;
- the ratio of stock market capitalisation to the GDP of the group of countries excluding *i*;
- the differential between the volatility of the stock market of country *i* and that of the group of countries excluding *i*;
- the differential between the volatility of the nominal effective exchange rate of country *i* and that of the nominal effective exchange rates of the group of countries excluding *i*;
- the stock of private sector securities in country *i*;
- the stock of public sector securities in country *i*;
- stock market trading volume in country *i*.

Table 6
Cross-section estimate at 1990Q2

Explanatory variables	Non-bank sector deposits held by G6	Banking sector deposits held by G6	Non-bank sector deposits held by G6 in reporting area	Banking sector deposits held by G6 in reporting area
Domestic GDP	1.210	0.415	–0.196*	0.044*
Foreign GDP	–1.030	–0.383*	5.940	1.360
Inflation difference	–0.021	–0.0011*	0.026	0.032*
Short-term rate difference	0.028	0.0083**	–0.015	–0.036*
Long-term rate difference	0.010*	0.026	0.033*	–0.016
Trade with G5	0.614	0.699	–0.870*	0.970
World trade	0.724	0.171*	–1.400	0.130*
Trade with world	–2.110**	–2.090	–3.150*	–1.940
G5 trade	–0.614*	0.907*	5.850	0.350*
Capitalisation/domestic GDP	0.097	0.090	–0.137	–0.021*
Capitalisation/foreign GDP	–0.075*	–0.170	0.441	0.282
Stock market volatility difference	–0.0049*	0.0230**	–0.021*	0.047
Exchange rate volatility difference	0.0166	0.014	0.028	0.0035*
Stock of private securities	0.834	0.595	–0.058	0.029*
Stock of public securities	0.882	1.000	0.444	–0.100*
Trading volume in stock market	–0.050*	–0.017*	–0.604	–0.086**
Interbank/bank deposits in G6	–0.011	0.011	0.0024*	0.00033*
Interbank/bank deposits in area	0.075	0.071	0.062*	0.238
R^2	0.93	0.94	0.56	0.83
DW	0.39	0.31	1.71	0.57

* Not significant at the 5% level. ** Not significant at the 10% level.

Table 7
Cross-section estimate at 1998Q2

Explanatory variables	Non-bank sector deposits held by G6	Banking sector deposits held by G6	Non-bank sector deposits held by G6 in reporting area	Banking sector deposits held by G6 in reporting area
Domestic GDP	1.180	0.189*	1.400	–0.478
Foreign GDP	–1.540	–0.505*	6.230	1.430
Inflation difference	–0.032	–0.029	0.061	–0.011
Short-term rate difference	0.030	0.021	–0.018*	0.0072
Long-term rate difference	–0.019	0.026	0.0002*	–0.024
Trade with G5	0.379*	0.416*	–2.210	0.919
World trade	0.949	0.529	–1.360	0.102*
Trade with world	–0.866*	–0.854*	–1.080*	–1.510
G5 trade	–1.230*	–0.198*	6.700	0.257*
Capitalisation/domestic GDP	0.145	0.099	–0.022*	–0.026*
Capitalisation/foreign GDP	0.052*	0.245	–1.110	0.733
Stock market volatility difference	0*	0.026**	0.042**	0.038
Exchange rate volatility difference	0.013	0.015	0.0196	–0.0029*
Stock of private securities	1.190	0.824	–0.651	0.161
Stock of public securities	0.535	0.867	–0.184*	–0.016*
Trading volume in stock market	–0.271	–0.249	–0.277*	–0.240
Interbank/bank deposits in G6	–0.012	0.012	0.0009*	0.0015
Interbank/bank deposits in area	0.061	0.056	0.102	0.234
R^2	0.92	0.95	0.64	0.85
DW	0.40	0.42	1.68	0.65

* Not significant at the 5% level. ** Not significant at the 10% level.

Tables 8 and 9 give the results of the regressions performed on the time series of cross-border deposits classified by the residence of the bank and the residence of the deposit holder, respectively. The upper part of each table reports the results of the time series estimates by country, whereas the lower part shows the results of the panel estimates.

As regards the estimates for the individual countries, *cross-border deposits held by foreign non-banks with resident banks in the country concerned* (Table 8) are directly linked to the GDP of the country in which the bank is located in all cases except Italy; elasticities vary between 1.63 in France and 3.65 in the United States, while the coefficient is not significant in Italy. Foreign GDP, which was expected to have a positive sign, is negative in the United States, Germany and France and not significant in the other three. Short-term interest rate differentials were expected to be positive, as a higher short-term rate in country *i* than in country *j* should attract funds to country *i*. However, the hypothesis was confirmed only in the case of the United States and the United Kingdom, while the estimated coefficient is negative in Italy and zero in the remaining three cases.

By contrast, the coefficients of long-term rate differentials should be negative under the hypothesis that they are a proxy for expected inflation rate differentials (i.e. for a given expected real rate in the two countries). The hypothesis is confirmed for the United States and France, while there is no significant relationship in Japan, Germany or Italy. The relation is significant but positive in the United Kingdom.

The current inflation differential is significant and negative, as expected, in two of the six cases (United States and France). In the other countries it is not significant.

Table 8

Cross-border deposits held by non-residents with banks in the country concerned

Equations in levels (quarterly data)						**Period 1985Q1–1998Q2**					
Dependent variable	Deposits by non-banks	R^2	Durbin Watson	Log (domestic GDP)	Log (foreign GDP)	Inflation diff.	Short-term rate diff.	Long-term rate diff.	Trade with G5	World trade	Trade with world
	United States	0.961	1.72	**3.65**	**–1.56**	**–0.026**	**0.0347**	**–0.0229**	**1.715**	**1.106**	***–2.24***
	Japan	0.92	1.63	***1.67***	–1.74	0.023	0.0096	0.045	0.08	–1	4.46
	Germany	0.993	1.38	**3.01**	**–5.11**	0.0168	–0.047	–0.0303	**–1.82**	0.53	1.35
	United Kingdom	0.983	2.12	**1.75**	–0.06	–0.0077	**0.0226**	***0.025***	0.503	0.24	–0.073
	France	0.987	1.67	**1.63**	***–3.97***	**–0.114**	0.017	**–0.073**	–0.187	0.525	1.86
	Italy	0.958	1.43	–3.14	–4.15	–0.029	**–0.048**	0.018	1.6	–1.8	–1.218
Dependent variable	Deposits by banks										
	United States	0.99	1.72	**2.38**	**1.07**	0.005	***0.018***	**0.02**	0.2	0.09	1.05
	Japan	0.953	1.71	**2.08**	**–5.63**	–0.03	–0.0027	0.0399	**2.66**	**5.63**	**–6.81**
	Germany	0.993	1.72	***0.797***	**–4.57**	0.014	0.0173	0.033	–0.61	0.741	0.744
	United Kingdom	0.989	1.82	0.223	**1.407**	**0.025**	0	0.012	0.264	–0.382	0.452
	France	0.996	2.15	0.043	**–0.989**	**–0.057**	**–0.039**	**–0.037**	0.161	**–0.905**	***1.497***
	Italy	0.947	1.22	–0.44	0.111	**–0.079**	**0.0609**	0.022	–0.233	–1.14	2.73
	Deposits by non-banks										
PANEL	OLS POOLED (*)	0.9	0.481	**1.92**	**–1.51**	–0.007	***0.0117***	**–0.028**	**–0.703**	**0.554**	0.929
	Deposits by banks										
PANEL	OLS POOLED (*)	0.908	0.228	**–0.7**	0.159	–0.0067	***0.0113***	0.0109	**1.575**	–0.174	**–3.505**

Table 8 (cont.)

Equations in levels (quarterly data) **Period 1985Q1–1998Q2**

Dependent variable	Deposits by non-banks	G5 trade	Capitalisation/ GDP	Stock exchange volatility diff.	Exchange rate volatility diff.	Log (private securities)	Log (public securities)	Log(trading volume)	Dummy Q1	Dummy Q2	Dummy Q3	Dummy Q4
	United States	–1.59	0.03	–0.002	***–0.0088***	**0.42**	0.015	0.044	**–4.303**	**–4.292**	**–4.272**	**–4.293**
	Japan	0.03	**0.38**	0.0397	–0.0164	0.32	0.33	–0.64	0.0001	–0.013	–0.074	–0.089
	Germany	***1.67***	**0.11**	***0.067***	–0.001	**1.31**	0.414	0.132	0.0129	–0.011	–0.0319	–0.0054
	United Kingdom	**–1.62**	**0.06**	–0.029	**0.00556**	–0.02	0.112	**0.193**	**0.198**	**0.197**	**0.188**	**0.192**
	France	–2	**0.08**	–0.025	**–0.026**	**3.35**	–0.905	–0.092	–0.046	–0.056	–0.062	–0.067
	Italy	**4.43**	**0.35**	0.056	0.017	**1.57**	**2.868**	–0.028	0.079	0.037	0.184	0.022
Dependent variable	Deposits by banks											
	United States	***–1.5***	**0.05**	–0.006	0.003	–0.04	–0.112	–0.028	**–3.844**	**–3.836**	**–3.827**	**–3.808**
	Japan	**–6.64**	**–0.29**	***–0.075***	0.007	**2.12**	***–1.24***	***0.67***	–0.08	0.19	0.06	0.044
	Germany	***2.08***	***0.09***	0.035	***–0.022***	***0.53***	**1.14**	0.12	***0.131***	0.092	***0.163***	0.047
	United Kingdom	0.047	**0.12**	–0.0147	0.0022	***–0.34***	**0.376**	***0.158***	**0.109**	0.073	0.107	**0.114**
	France	0.946	**0.06**	**–0.027**	**–0.0139**	**1.63**	0.051	0.084	0.047	0.039	**0.141**	0.043
	Italy	–0.926	0.13	0.054	0.0127	**2.56**	–0.562	0.09	–0.179	–0.203	–0.209	–0.169
	Deposits by non-banks											
PANEL	OLS POOLED (*)	–0.511	**0.14**	0.0162	***0.0063***	**0.858**	**0.556**	***–0.138***	0.0084	0.0054	–0.014	–0.0099
	Deposits by Banks											
PANEL	OLS POOLED (*)	**1.267**	***–0.029***	**0.0404**	**0.0171**	**0.956**	**0.871**	**0.209**	–0.0048	–0.028	0.017	0.013

The coefficients in bold are significant at the 5% level; those in italics and bold are significant at the 10/15% level.

Table 9

Cross-border deposits held by residents in the country concerned with non-resident banks

Equations in levels (quarterly data)						**Period 1985Q1–1998Q2**					
Dependent variable	Deposits by non-banks	R^2	Durbin Watson	Log (domestic GDP)	Log (foreign GDP)	Inflation diff.	Short-term rate diff.	Long-term rate diff.	Trade with G5	World trade	Trade with World
	United States	0.988	1.96	–0.233	–0.175	–0.0016	**–0.007**	0.004	–0.0014	**0.411**	0.016
	Japan	0.953	1.14	***0.831***	**–4.2**	–0.005	–0.011	***0.057***	0.363	**2.44**	–0.453
	Germany	0.989	1.53	**1.08**	–0.136	**–0.026**	**0.031**	***0.042***	**1.54**	–0.381	**–4.11**
	United Kingdom	0.979	1.35	0.263	**–1.49**	–0.007	0.00025	0.022	**1.25**	0.067	**–3.11**
	France	0.967	1.48	**2.75**	**–4.85**	–0.029	0.0021	**–0.157**	**–2.28**	–1.01	**5.76**
	Italy	0.917	0.817	**2.77**	**–2.67**	0.002	**–0.047**	0.04	**–2.92**	–0.419	**7.31**
Dependent variable	Deposits by banks										
	United States	0.949	1.94	–0.211	0.009	0.0112	**–0.0228**	0.011	**0.688**	0.204	–0.564
	Japan	0.963	1.77	**1.514**	**–4.15**	***–0.019***	–0.012	–0.0083	**0.827**	**2.46**	**–2.57**
	Germany	0.937	1.6	**0.917**	**1.42**	–0.0127	**–0.041**	**0.059**	0.367	–0.666	–2.03
	United Kingdom	0.953	1.61	–0.378	**1.573**	**0.0241**	**–0.0167**	–0.006	–0.0688	–0.799	**1.09**
	France	0.746	1.98	–0.854	0.686	**–0.101**	***0.046***	**0.125**	**3.32**	**3.1**	–1.98
	Italy	0.769	1.36	0.473	–1.77	0.0008	–0.0166	–0.017	***1.32***	**1.65**	***–2.43***
	Deposits by non-banks										
PANEL	OLS POOLED (*)	0.526	1.62	**1.845**	**2.51**	–0.0053	***–0.017***	**0.025**	**–1.22**	–0.248	–1.25
	Deposits by banks										
PANEL	OLS POOLED (*)	0.665	0.624	**0.645**	0.178	**0.0098**	**–0.01**	**–0.036**	**0.702**	–0.106	–0.938

Table 9 (cont.)

Equations in levels (quarterly data)						**Period 1985Q1–1998Q2**						
Dependent variable	Deposits by non-banks	G5 trade	Capitalisation/ GDP	Stock exchange volatility diff.	Exchange rate volatility diff.	Log (private securities)	Log (public securities)	Log(trading volume)	Dummy Q1	Dummy Q2	Dummy Q3	Dummy Q4
	United States	–0.215	**0.0148**	**0.034**	***–0.0026***	**0.303**	0.141	–0.028	–0.575	–0.578	–0.568	–0.591
	Japan	–1.73	***0.083***	***0.042***	0.0047	**0.627**	–0.336	0.164	–0.048	–0.113	–0.02	–0.119
	Germany	**1.02**	–0.022	***0.047***	0	**0.489**	**0.546**	***–0.183***	0.0247	0.0372	0.0589	0.0316
	United Kingdom	**1.15**	–0.032	**–0.072**	0.0016	**0.843**	0.063	**0.288**	–0.022	–0.049	–0.014	–0.0474
	France	**2.09**	**–0.104**	–0.018	–0.013	**2.16**	***–1.03***	**0.478**	0.098	0.0825	**0.236**	0.076
	Italy	–0.461	–0.083	**0.114**	0.0083	**2.04**	***–1.67***	0.271	–0.125	–0.201	–0.155	–0.217
Dependent variable	Deposits by banks											
	United States	–0.438	**0.028**	–0.012	**0.0169**	***0.077***	0.435	–0.031	–1.67	–1.65	–1.64	–1.653
	Japan	**–2.42**	–0.027	–0.03	0.0028	**1.298**	–0.342	0.177	–0.0074	–0.076	0.037	–0.0259
	Germany	**1.61**	**0.072**	**0.0683**	–0.0023	***0.334***	***–0.483***	–0.166	–0.082	–0.06	–0.061	0.0203
	United Kingdom	**0.878**	**0.067**	**0.03**	–0.002	**–0.327**	0.077	–0.015	0.034	0.023	0.047	0.042
	France	**–8.65**	**0.167**	0.069	0.014	–0.358	–0.231	–0.296	0.077	0.032	–0.087	0.0896
	Italy	**1.72**	–0.01	–0.033	0.0014	**–1.003**	**0.931**	0.058	0.057	0.056	0.057	0.09
	Deposits by non-banks											
PANEL	OLS POOLED (*)	**3.17**	–0.054	0.0072	**0.0237**	0.159	–0.089	**–0.587**	0.032	**0.066**	**–0.092**	0.0073
	Deposits by Banks											
PANEL	OLS POOLED (*)	0.232	***0.016***	**0.058**	–0.004	**0.175**	***–0.211***	–0.067	–0.012	–0.011	0.008	**0.026**

The coefficients in bold are significant at the 5% level; those in italics and bold are significant at the 10/15% level.

The four measures of trade adopted in the study – world trade (the sum of exports and imports expressed in billions of dollars), trade between the country concerned and the remaining G5 countries, trade between the reporting area and the country concerned, and trade between the rest of the world and the country concerned – should be positively correlated with the behaviour of cross-border deposits but turn out to be so in only six of the 24 cases.

As could be expected on the basis of Charts 8 and 9, the variables that measure the "financialisation" of the six countries are more strongly correlated with deposits: the ratio of market capitalisation to GDP is positive and significantly different from zero in all cases except for the United States. The stock of private sector securities is significant except in Japan and the United Kingdom, while the stock of public sector securities is significant only in Italy. The volatility differentials between the domestic and foreign market and stock market trading volume are significant in only a few cases. The seasonal dummies in the equations do not reveal any significant seasonality for any of the series considered.

The same conclusions can be drawn from the *regressions by country performed on cross-border deposits held by banks located in the G6*. Output has a positive sign in three out of six cases (United States, Japan and Germany), while it is not significant in the others. Foreign GDP is positive only for the United States and the United Kingdom. The current inflation differential is negative only in Italy and France, while the expected inflation differential, measured by the long-term interest rate differential, is negative only in France. The short-term rate differential has the expected sign in the United States and Italy, whereas trade has the expected sign in one sixth of the cases, as before.

The aggregate regression performed on the panel of the six countries for the period between the first quarter of 1985 and the second of 1998 produces similar results to those obtained for the individual countries.

Table 9 gives the estimates performed on cross-border deposits held by *bank and non-bank residents of the countries concerned* with banks located abroad. In this case, the expected sign of some variables is the opposite of that in the previous regressions because we are studying deposits held abroad by residents, not deposits held by non-residents in the country concerned. This is the case with the short- and long-term rate differentials, the current inflation differential and the differential in the volatility of the stock market and nominal effective exchange rates. Domestic GDP has the expected sign in four cases (Japan, Germany, France and Italy) for deposits held by non-bank residents and two cases (Japan and Germany) for deposits held by banks. The short-term rate differential has the expected sign in two cases (United States and Italy) for non-banks and three cases for banks. Trade has the expected sign in nine out of 24 cases for deposits held by non-banks, 10 out of 24 for those held by banks. The ratio of stock market capitalisation to GDP is significant in two and four of the six cases respectively, while the stock of private-sector securities is significant in three of six. The stock of public sector securities is significant and has the expected sign only for Germany in the case of deposits held by non-banks and for Italy in the case of deposits held by banks.

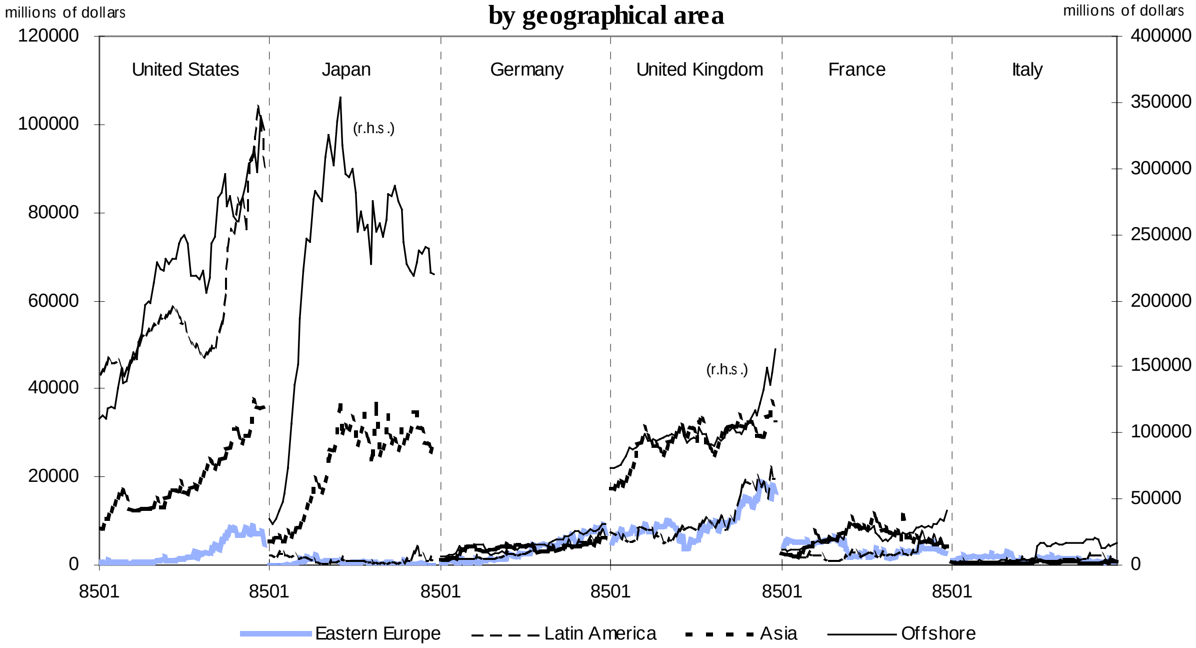
The panel estimates provide good results, especially for deposits held by banks with non-resident banks, where only the long-term rate differential and the stock of public sector securities do not have the expected sign. In the case of deposits held by non-banks, it is primarily the financial scale variables (capitalisation/GDP and the stock of securities) that are not significant.

Summing up, although the equations for the individual countries have R-squared close to unity, it is necessary to bear in mind that this is the predictable result of regressions performed on time series with first-order autoregressive process with a coefficient not significantly different from unity. Under such conditions, the equation estimated must be considered a static, long-run equation. It is not possible to introduce lags. The dynamic setting can only be studied in a second stage, estimating the same equation in terms of first differences and introducing the residual of the static equation estimated previously in order to take account of the constraints imposed by the long-run relationship on the short-term dynamics.

3.4 Analysis by geographical area

Charts 10 and 11 provide another classification of cross-border deposits. Chart 10 shows *deposits held with banks in the G6 countries* by bank and non-bank residents of four "non-reporting" areas (offshore centres, Latin America, Asia excluding Hong Kong and Singapore, and eastern Europe). Note the rapid growth in deposits held by bank and non-bank agents from offshore centres: in mid-1998 they held \$350 billion and \$100 billion in US and Japanese banks respectively, compared with just under \$50 billion and \$25 billion in 1985. However, deposits by Japanese residents fell sharply at the end of the 1980s, in conjunction with the bursting of the speculative bubble that had driven up securities prices. Residents in Latin America primarily deposit funds in the United States: this activity began to expand rapidly at the start of the 1990s, and since then deposits have nearly doubled from \$50 to \$100 billion. Chart 11 shows *loans made by resident banks in the G6 countries* to bank and non-bank residents of the four areas specified above. Loans to residents of offshore centres by Japanese banks increased very rapidly, rising to about \$600 billion by mid-1998. Asia also emerges as the area of specialisation for Japanese lending, with loans to Asian countries soaring from \$10 billion at the start of 1985 to nearly \$70 billion in mid-1998.

Chart 10
Deposits of banks and non-banks held with banks in the G6, by geographical area

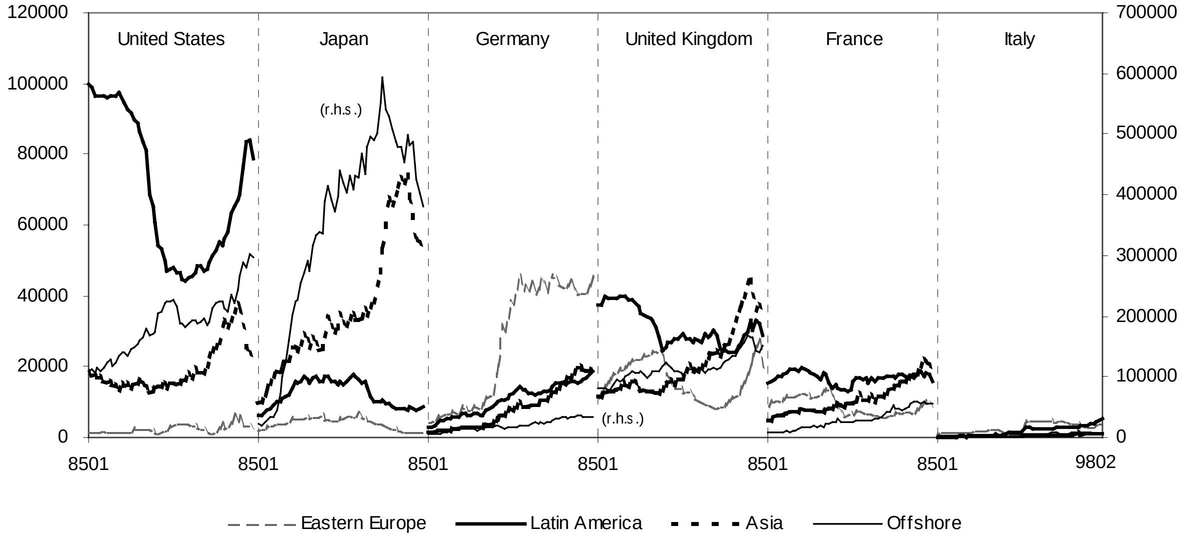


German banks have specialised in eastern Europe. The rise in lending to countries in the area from \$10 billion at the end of the 1980s to about \$50 billion in mid-1998 mainly came after German unification. Latin America is the prime destination for loans from US banks, although they showed little interest in the area until the start of the 1990s, when lending reached a low point of about \$50 billion.

As in the previous regressions, trade and wealth (as approximated by GDP) should be the main explanatory variables for the behaviour of deposits and loans classified by geographical area. Nevertheless, these series show a pronounced degree of specialisation by geographical area. This aspect is not accounted for in the estimates but it could explain a significant part of lending decisions and therefore undermine the reliability of the estimations. For a preview, Charts 12–15 show the behaviour of deposits held in the G6 countries by banks resident in the four areas and the lending by banks resident in the G6 countries to bank and non-bank residents in the four areas, together with the series that are expected to explain their behaviour.

Chart 11

Lending by banks in the G6 to banks and non-banks, by geographical area (millions of dollars; from 1985Q1 to 1998Q2)



Tables 10 and 11 report, respectively, the results of the regressions performed on deposits held by bank and non-bank agents resident in the four areas with banks resident in the G6 countries. As before, the estimates were performed for individual countries and for a panel of the six countries taken together (only one subset of the variables used earlier has been used in the regressions performed for the geographical areas). The R-squared of the panel regression performed for deposits by banks (Table 10, last section) range between 0.62 for depositors resident in eastern Europe and 0.96 for those in Asia. Domestic GDP has the expected sign for Asia and eastern Europe, while foreign GDP has the expected sign for eastern Europe and, marginally, for Latin America. The short-term interest rate differential is positive in all cases, while the long-term differential is negative but not significantly different from zero for Asia only. World trade has the expected sign in all cases, while trade between the individual areas and the G6 countries has a positive sign only for Latin America and eastern Europe. The current inflation differential has a negative sign for Latin America and Asia and, marginally, the offshore countries. For the panel regressions performed on deposits by non-banks (Table 11, last section), domestic GDP has a positive sign in all cases, with elasticities that vary from 0.39 for Asia to 1.0 for offshore countries (in other words, a 1% GDP growth prompts a 1% increase in deposits from the specified area).

Foreign GDP has the correct sign for offshore countries, Latin America and eastern Europe; it is negative for Asia. The short-term interest rate differential is positive only for Asia, while the long-term differential has the expected negative sign for offshore countries and Asia. World trade directly influences deposits by foreign non-banks in Latin America and Asia, while trade between the areas under consideration and the G6 countries had an impact for Asia and eastern Europe.

As a follow-up to these estimates, one could specify the equations in a more complete fashion by adding other regressors, most important the stock of private sector securities and the volatilities of exchange rates and stock markets, which strongly influenced investment decisions in these countries. In addition, one should also carry out regressions for loans granted by banks located in G6 countries to bank and non-bank residents of the four areas considered.

Chart 12a

Offshore countries

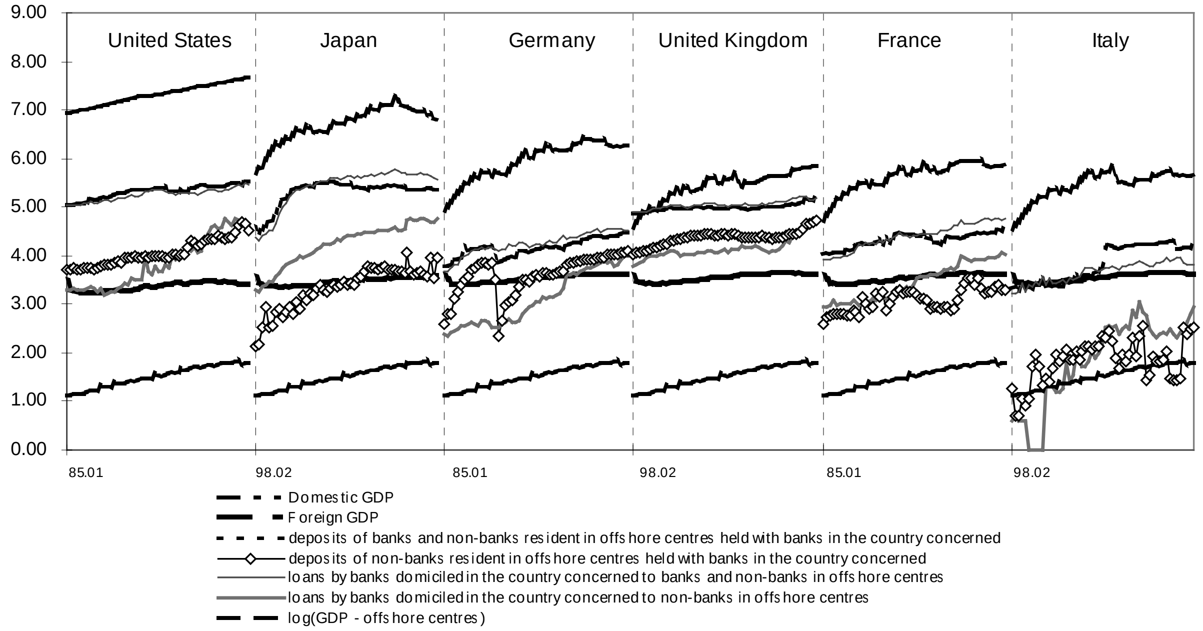


Chart 12b

Offshore countries

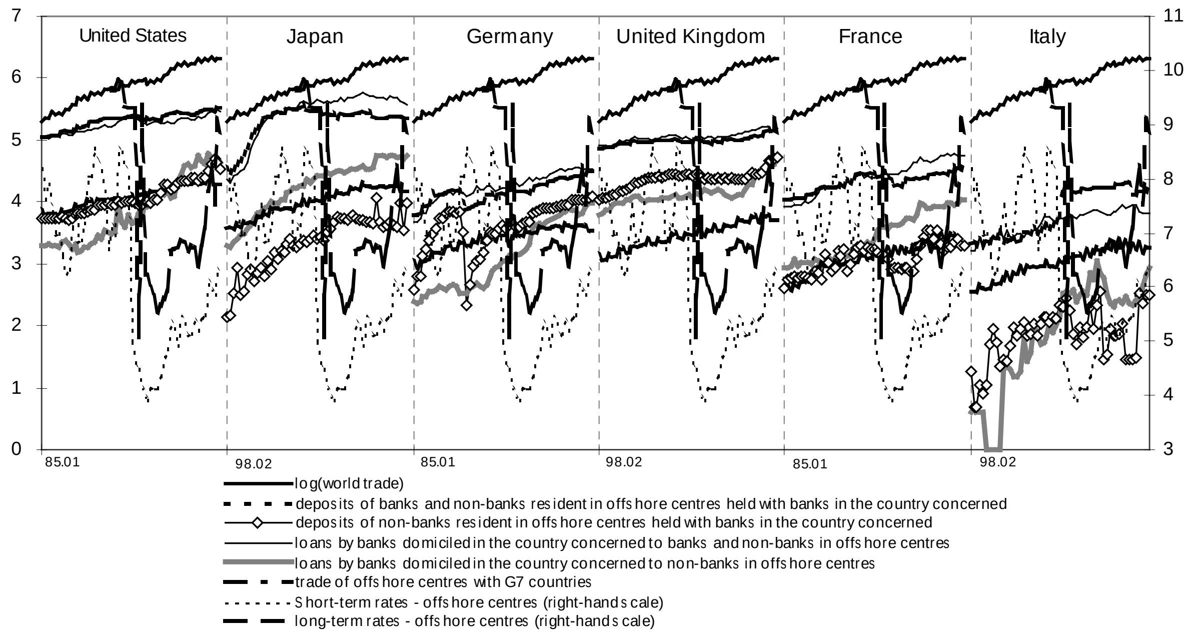


Chart 13a

Latin America

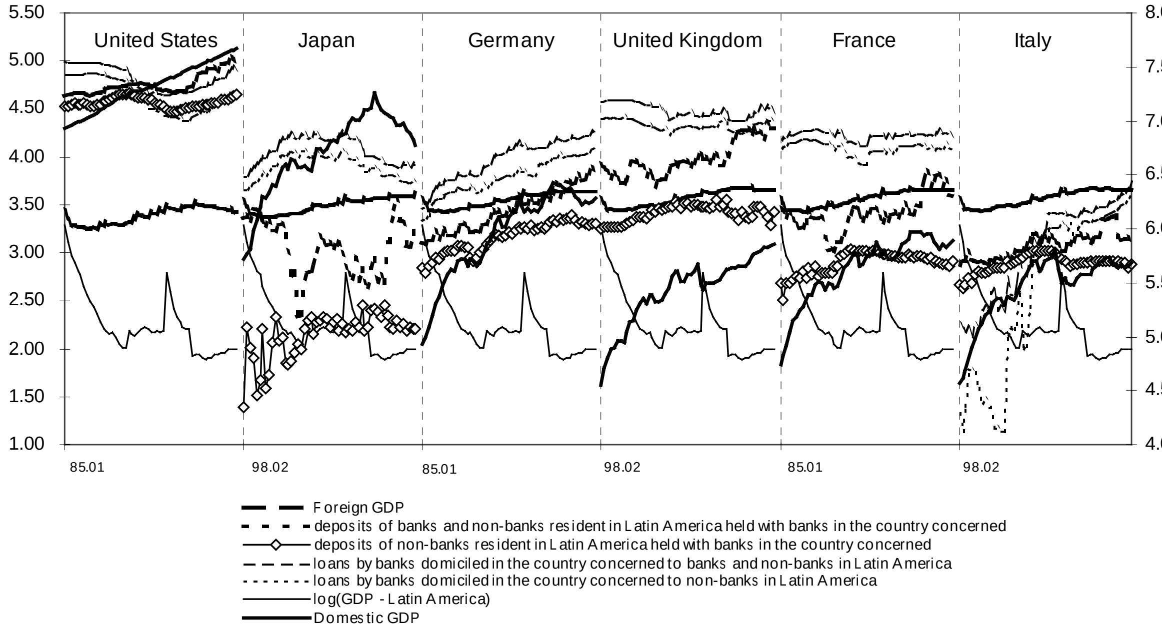


Chart 13b

Latin America

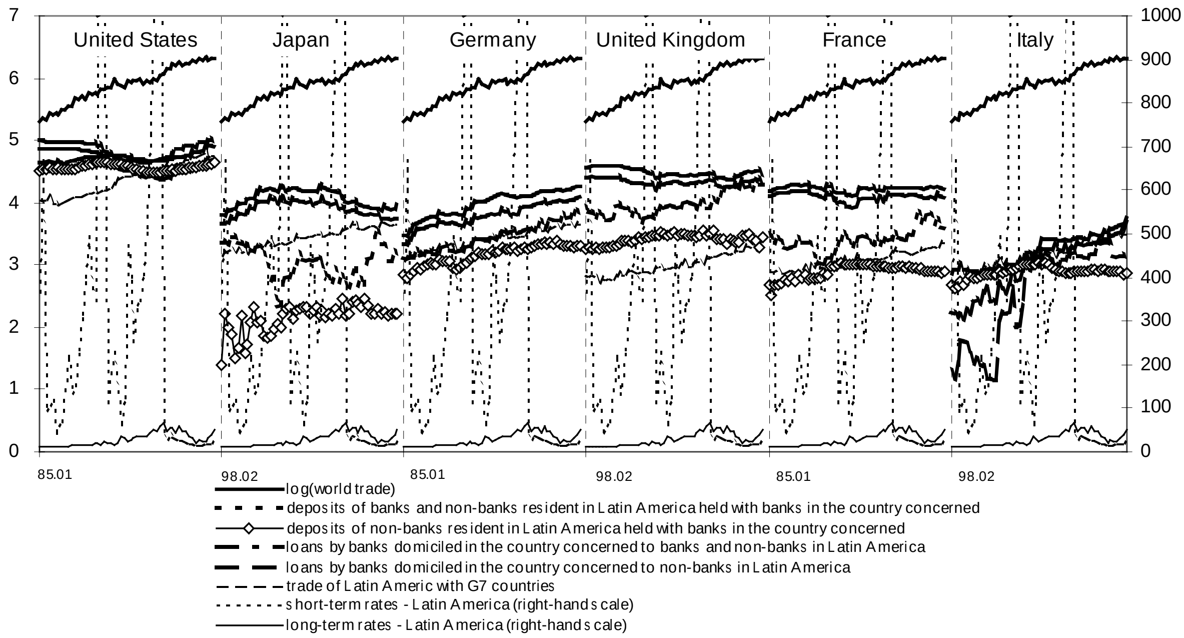


Chart 14a

Asia

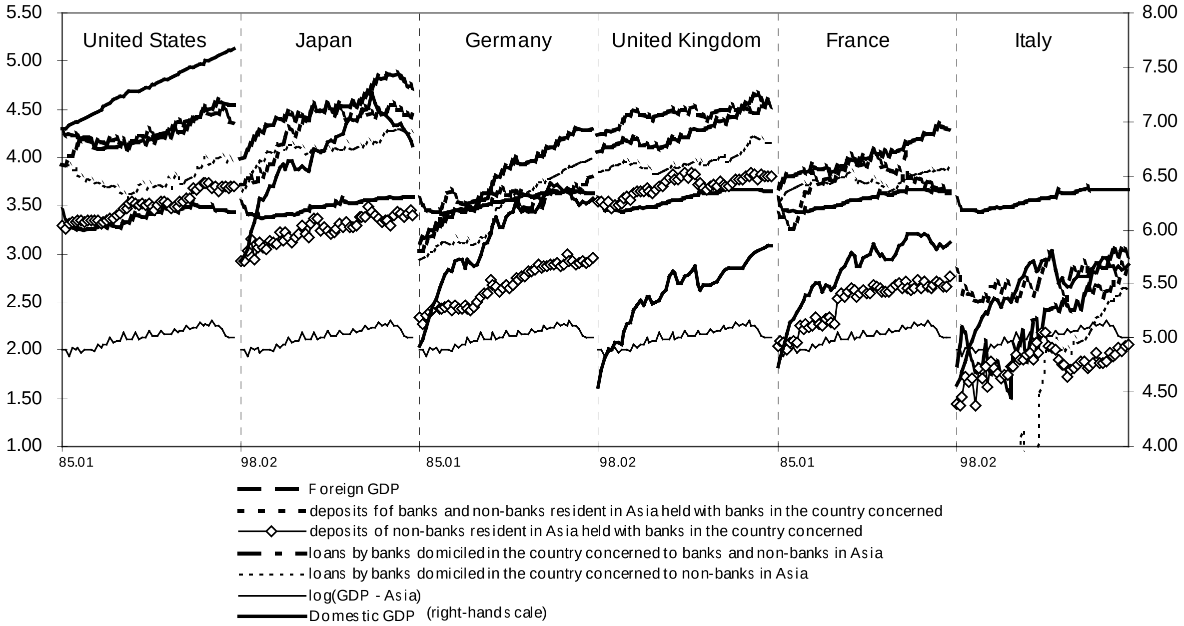


Chart 14b

Asia

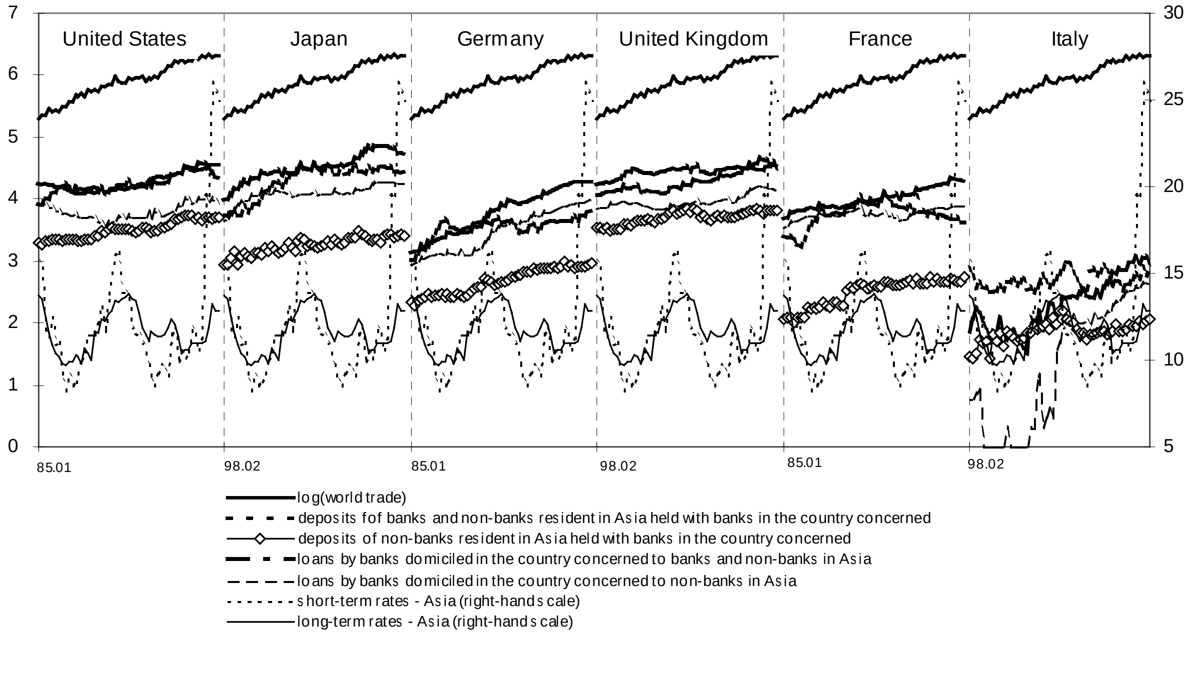


Chart 15a

Eastern Europe

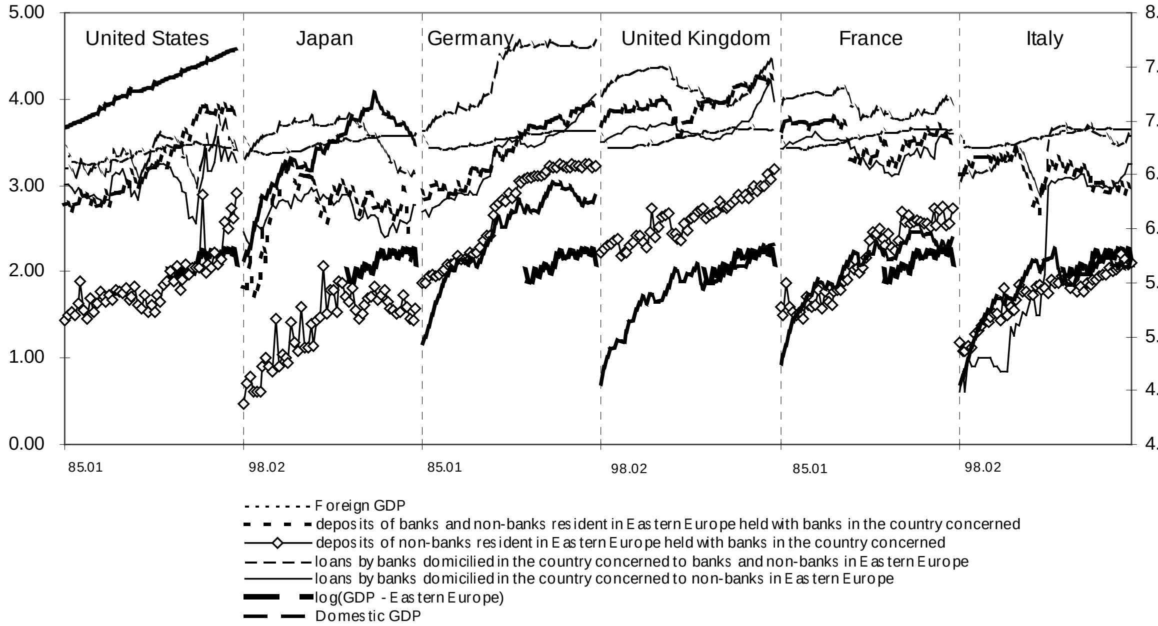


Chart 15b

Eastern Europe

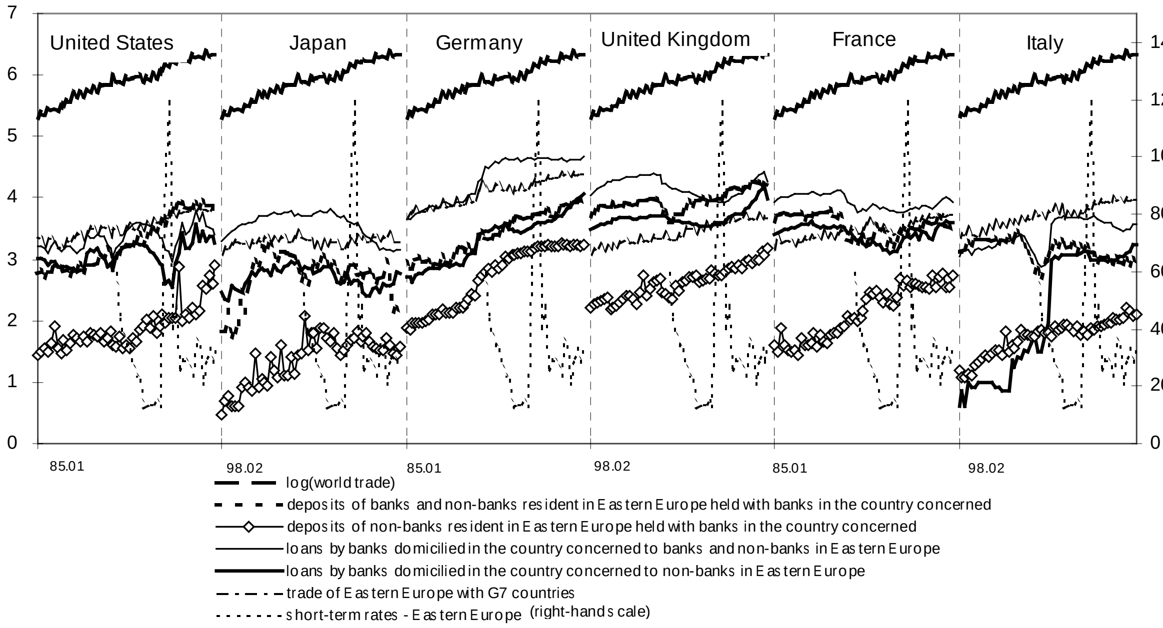


Table 10

Equations for deposits held with banks in the G6 by banks located in the specified geographical areas

	R^2	DW	Domestic GDP	Foreign GDP	Short-term rate differential	Long-term rate differential	World trade	Area's trade with G7	Inflation differential	Market capitalisation/GDP of country concerned
United States – Deposits of banks resident in:										
Offshore centres	0.91	0.81	–1.33**	1.72	–0.004*	–0.009*	1.22	–0.227**	0.037 [1]	0.095
Latin America	0.91	0.86	1.32*	–0.19*	0.00011*	0.0036**	–1.14*	1.30	0.0017	–0.201
Asia	0.85	0.84	5.46	–2.24	0.049*	0.055	–1.28	1.16	0.0039*	–0.164
Eastern Europe	0.96	1.43	1.00*	0.192	–0.0006*	–	0.938*	0.608	–0.111 [1]	–0.229
Japan – Deposits of banks resident in:										
Offshore centres	0.79	0.95	2.66	–8.20	0.055**	0.0029*	2.37	0.512*	0.280 [1]	0.283
Latin America	0.45	1.23	–1.54**	–0.06*	0.0013	0.017**	–0.443*	0.442*	–0.009	0.592
Asia	0.84	0.65	–0.328*	–1.30*	0.013*	0.076	3.55	–0.98*	–0.05*	–0.519
Eastern Europe	0.56	0.94	3.38	–0.506	0.010	–	–0.837*	0.520*	0.202* [1]	–0.042*
Germany – Deposits of banks resident in:										
Offshore centres	0.84	1.46	0.64	0.49*	0.0016*	–0.034**	0.376	–0.204	–0.076 [1]	0.059*
Latin America	0.91	2.02	–1.17	0.523	0.00029	0.00076*	4.13	–0.252*	–0.0032	0.0103
Asia	0.68	0.72	0.309*	–3.56	0.0182*	0.181	1.174**	–0.330*	–0.055**	0.296
Eastern Europe	0.94	0.69	–0.121*	0.268	0.0018**	–	1.16	0.578	0.034 [1]	–0.113
United Kingdom – Deposits of banks resident in:										
Offshore centres	0.82	1.20	–0.122**	–1.48	–0.0071**	0.0129**	0.583	0.189	–0.003 [1]	0.161
Latin America	0.77	1.23	–1.886	0.250*	0.00042	0.0042*	0.831*	2.08	–0.002*	0.116*
Asia	0.78	0.85	0.621	–0.595*	0.0089**	0.040	0.249*	0.109*	–0.042	–0.0101
Eastern Europe	0.76	1.12	–1.61	0.025*	0.0034	–	1.06**	0.667	0.049** [1]	0.324
France – Deposits of banks resident in:										
Offshore centres	0.81	0.79	0.388**	–1.57	0.027	–0.021*	1.82	0.0048*	0.104** [1]	0.032*
Latin America	0.515	1.04	–1.98	0.78**	0.0011	0.0064*	3.04	0.209*	–0.0057**	0.268*
Asia	0.698	0.94	1.42	–1.31*	0.053	–0.042**	–0.505*	–2.24	–0.139	–0.237**
Eastern Europe	0.40	0.63	–1.30	–0.042*	0.0015*	–	–0.075*	–0.035*	0.013 [1]	0.457
Italy – Deposits of banks resident in:										
Offshore centres	0.93	1.34	–0.472**	3.16	0.088	0.057**	1.33	–0.138*	–0.314 [1]	–0.043*
Latin America	0.56	0.78	–1.79	–0.43*	0.0006	0.0008*	0.772*	1.76	–0.0061	–0.232*
Asia	0.20	1.09	–0.046*	–3.52	–0.026*	0.035*	2.39	–0.28*	0.005*	–0.719
Eastern Europe	0.26	0.74	–0.102*	–0.032*	0.0024*	–	1.95	–1.70	–0.155* [1]	–0.132*
PANEL – Deposits of banks resident in:										
Offshore centres	0.94	0.21	0.161*	–0.704	0.0018*	0.064	1.64	–0.072*	–0.051** [1]	0.054*
Latin America	0.88	0.56	–1.74	0.008*	0.0008	0.002*	1.37	0.96	–0.005	0.141
Asia	0.96	0.56	0.515	–2.59	0.033	–0.0067*	1.22	–0.83	–0.042	–0.132
Eastern Europe	0.614	0.11	0.613	0.109	0.007	–	0.622	0.558	0.122 [1]	–0.480

* Not significant at the 5% level. ** Not significant at the 10/15% level. [1] Inflation in the G6 country concerned.

Table 11

Equations for deposits held with banks in the G6 by banks located in the specified geographical areas

	R^2	DW	Domestic GDP	Foreign GDP	Short-term rate differential	Long-term rate differential	World trade	Area's trade with G7	Inflation differential	Market capitalisation/GDP of country concerned
United States – Deposits of non-banks resident in:										
Offshore centres	0.94	0.89	3.43	–3.33	0.0045*	0.011**	0.036*	0.286	–0.053** [1]	–0.038**
Latin America	0.68	0.76	0.143*	–0.019*	–0.00005	0.0021	0.147*	–0.113**	0.0006	0.0115*
Asia	0.89	0.67	0.097*	0.244*	–0.005*	0.007*	0.359**	0.078*	0.0048*	–0.030
Eastern Europe	0.68	2.02	–0.912*	0.168	0.0028	–	1.14**	–0.05*	–0.204 [1]	0.074**
Japan – Deposits of non-banks resident in:										
Offshore centres	0.90	1.94	0.684	0.733*	0.015*	0.027*	–0.147*	0.0086*	0.0286* [1]	0.0854*
Latin America	0.54	1.57	–0.457**	–0.05*	0*	–0.0025*	1.19**	–0.013*	–0.0011*	–0.166**
Asia	0.85	1.93	0.051*	–0.419*	–0.004*	0.0093*	0.496	–0.180**	–0.002*	–0.061**
Eastern Europe	0.76	1.90	0.76	–0.154	–0.0013*	–	0.692**	–0.533	0.009* [1]	0.0073*
Germany – Deposits of non-banks resident in:										
Offshore centres	0.69	1.18	2.70	2.40	–0.058	–0.072**	–2.68	–0.55	–0.068* [1]	0.217**
Latin America	0.95	1.28	0.372	0.102	0.00003**	0.00011*	0.152*	–0.063*	–0.0002*	0.0242*
Asia	0.92	0.73	0.370	0.767	–0.0045*	–0.0405	–0.157*	–0.128*	0.0042*	0.036*
Eastern Europe	0.97	0.86	0.646	0.122	–0.0003*	–	–0.406**	0.579	0.077 [1]	–0.046*
United Kingdom – Deposits of non-banks resident in:										
Offshore centres	0.95	1.44	0.623	0.375	0.0069	–0.0054*	–0.449	–0.052**	0.019 [1]	0.109
Latin America	0.79	1.42	0.56	0.089	–0.0008	0.0008*	–0.199**	0.027*	0.00015*	–0.065
Asia	0.86	1.04	0.442	–0.024*	0.0039**	–0.015	–0.087*	0.0469*	0.0044*	–0.0063*
Eastern Europe	0.89	1.60	–0.422**	–0.019*	0.0011**	–	0.672	0.408	0.0148* [1]	0.049*
France – Deposits of non-banks resident in:										
Offshore centres	0.73	1.31	–0.007*	–2.05	0.004	–0.048*	2.41	0.0049*	0.073** [1]	–0.159
Latin America	0.79	1.25	0.723	0.090**	–0.00006	0.0014**	–0.271**	0.071*	0.00013*	–0.026*
Asia	0.92	1.23	0.526	0.019*	0.004*	–0.036	0.064*	–0.141*	–0.007*	–0.038*
Eastern Europe	0.90	1.33	0.167*	0.120	–0.0018**	–	0.534**	0.499	0.011* [1]	–0.178
Italy – Deposits of non-banks resident in:										
Offshore centres	0.58	1.22	1.87	1.18**	–0.035**	–0.0089**	–2.03	0.122*	0.084* [1]	–0.027*
Latin America	0.92	1.82	0.561	0.122	–0.00006	0.0008**	–0.156**	0.075**	0.0006	–0.041
Asia	0.71	1.65	0.622	–0.262*	–0.011**	0.017**	–0.149*	0.071*	0.0086*	0.023*
Eastern Europe	0.91	1.86	0.751	0.083	0*	–	–0.593	0.256	0.045** [1]	0.180
PANEL – Deposits of non-banks resident in:										
Offshore centres	0.94	0.74	1.00	1.01	–0.0098**	–0.028	–0.765	–0.052*	0.0173* [1]	0.0067*
Latin America	0.99	1.28	0.510	0.138	–0.00007	0.0015	0.216	–0.194	0.00044	–0.0079*
Asia	0.99	0.77	0.390	–0.216	0.0017*	–0.026	0.106**	0.200	0.00088*	–0.0079*
Eastern Europe	0.91	1.03	0.813	0.117	–0.0011	–	–0.631	0.351	0.037 [1]	0.063

* Not significant at the 5% level. ** Not significant at the 10/15% level. [1] Inflation in the G6 country concerned.

Bibliography

Alworth, J S and S Andresen (1992): "The determinants of *cross border* non-bank deposits and the competitiveness of financial market centres". *Money Affairs*, Vol. 5, pp. 105-33.

Banca d'Italia (1998a): *Economic Bulletin*, No. 30, February.

Banca d'Italia (1998b): *Economic Bulletin*, No. 31, October.

BIS (1995): *International Banking and Financial Market Developments*, February.

BIS (1998): *International Banking and Financial Market Developments*, August.

BIS (1999): *International Banking and Financial Market Developments*, March.

Eichengreen, B and D Mathieson (1998): "Hedge Funds and Financial Market Dynamics". *IMF Occasional Paper*, No. 166, May.

Fratianni, M and P Savona (1972): "La liquidità internazionale – Proposta per la ridefinizione del problema". *Il Mulino*, Bologna.

Garber, P M (1998): "Derivatives in International Capital Flow". *NBER Working Paper*, No. 6623, June.

Giannini, C and C Monticelli (1996): "Liquidità internazionale e depositi *cross border*". Preparatory paper for the Bank of Italy's 1995 *Annual Report*, mimeo.

IMF (1998): "Interim Report on the World Economic Outlook and the International Capital Markets". December.

La Porta, R, F Lopez-de-Silanes, A Shleifer and R W Vishny (1999): "Law and Finance". *Journal of Political Economy*, forthcoming.

Sheldon, G (1992): "Explaining the Cross-country Distribution of International Bank Deposits", in M Blattner, H Gerber and A Swoboda (eds.), *Competitiveness in banking*.

Tristani, O (1998): "Liquidità 'mondiale' e controllo monetario". Preparatory paper for the Bank of Italy's 1997 *Annual Report*, mimeo.

International diversification of investments in Belgium and its effects on the main Belgian securities markets

Thierry Timmermans

1. Introduction

The international diversification of investments is far from being a recent phenomenon in Belgium. Over the past 20 years, individuals markedly stepped up their purchases of foreign currency denominated assets such that, on the eve of EMU, these assets represented a greater share of private wealth than in most other European countries. The introduction of the euro should, however, provide fresh impetus to and a broader base for this process of diversifying out of domestic assets. This is bound to have profound repercussions on the Belgian financial markets, in particular the government securities market and the stock market. These markets will not be able to benefit to the same extent as in the past from a stable core of captive investors, and it is far from certain that this reduced interest on the part of traditional customers can be fully offset by increased purchases by investors from other euro area countries.

The first part of this note provides a snapshot of the current degree of international diversification of financial assets and liabilities in Belgium. The second and third parts examine the present and future implications of the introduction of the euro on the government securities market and the stock market respectively, and briefly describe the adjustments envisaged by these two markets.

2. International diversification of financial assets and liabilities in Belgium

The very high saving rate among Belgian individuals has been reflected in an accumulation of financial assets, which at end-1998 totalled close to three times GDP. How these savings are invested obviously exerts a powerful influence on the structure of Belgian financial markets.

In this context, there have been two major developments over the last 20 years. First, the overall share of financial assets in foreign currency rose from 7% in 1980 to 23% in 1998 (Table 1). Second, the role of banks in attracting savings declined markedly during the same period, with banks' market share falling from 60% to 37% in favour of direct purchases of securities and, above all, investments with institutional investors, in particular collective investment undertakings (UCITS).

It is interesting to note that these two developments were not independent but, on the contrary, went hand in hand. The diversification of individuals' investments into foreign currency occurred to a much greater extent via investments with institutional investors and direct purchases of securities than via more traditional financial intermediaries such as banks.

This does not, however, mean that financial intermediaries have not played any accompanying role in this development. Almost all UCITS are set up, administered and marketed by Belgian banks, which thereby manage to recuperate, in the form of fee income, the falls in revenue resulting from the contraction in their intermediation income. The diversification opportunities and professional management offered by these funds have greatly facilitated the growth of individuals' foreign currency investments. At the same time, however, this interest in foreign currency denominated assets has also been reflected in a rise in direct purchases of securities.

This diversification of investments, be it by channel or currency, has not been driven by the purely financial consideration of attaining a better risk-return combination. It has also had a fiscal motive as a means of escaping the withholding tax on investment income. As individuals' capital gains are not taxed in Belgium, investments via UCITS are de jure exempt from withholding tax insofar as the UCITS do not distribute their income but capitalise it. A de facto exemption exists for direct purchases of securities abroad in that the beneficiary can then easily omit to declare his income to the Belgian authorities.

Table 1
Structure of financial assets held by individuals[1]
(as a percentage of the total)

	1980	1998
Investments with credit institutions	**60.4**	**36.9**
of which: share in francs	97.6	93.0
share in foreign currency	2.4	7.0
Investments with insurance companies and pension funds[2]	**7.3**	**11.8**
of which: share in francs	91.9	82.4
share in foreign currency	8.1	17.6
Investments with UCITS[2]	**0.5**	**14.1**
of which: share in francs		48.3
share in foreign currency		51.7
Direct purchases of securities	**31.9**	**37.3**
of which: share in francs	78.3	63.5
share in foreign currency	21.7	36.5
Total	**100.0**	**100.0**
of which: share in francs	92.6	76.7
share in foreign currency	7.4	23.3

[1] Excluding shares held in unlisted companies. [2] The currency breakdown of investments by individuals with institutional investors is assumed to be identical to that of financial assets held by these institutional investors.

Source: National Bank of Belgium (NBB).

Whatever the reasons, these foreign currency investments by individuals constituted a major source of capital outflows over the past 20 years and thereby a constraint on the balance of payments, as, to achieve its fixed exchange rate objective, Belgium had to counterbalance these outflows with offsetting inflows. This requirement was obviously more difficult to meet at times when the current account was in deficit, as in the early 1980s. The re-establishment of a surplus and its gradual widening from 1986 onwards alleviated this constraint, without, however, eliminating it, as the current account balance was often insufficient to counterbalance the capital outflows resulting from investments made abroad by individuals.

There have been two main types of offsetting inflows of capital. The first, autonomous in nature, has been in the form of direct investments. The rest of the world's holding of shares in Belgian companies has increased steadily, from 12.6% to 29.1% (Table 2). This rise has not been limited to listed stocks but has extended to unlisted equities, which in Belgium are by far the commonest means of raising capital.

The second major source of capital inflows has been the issuance of foreign currency denominated bonds by the government. This activity has been endogenous in nature since its goal has been precisely to offset the balance on current and other capital account transactions.

Table 2
Shareholder structure of Belgian companies
(as a percentage of the total)

	1980	1998
Listed shares		
Individuals	51.9	19.0
Companies	20.4	37.4
Other residents*	15.1	13.1
Rest of the world	12.6	30.5
Total	100.0	100.0
Unlisted shares		
Individuals	63.6	39.9
Companies	22.4	30.9
Other residents*	1.5	1.2
Rest of the world	12.6	28.0
Total	100.0	100.0
Total shares		
Individuals	61.2	30.8
Companies	22.0	33.7
Other residents*	4.2	6.4
Rest of the world	12.6	29.1
Total	100.0	100.0

* Including Belgian credit institutions and Belgian and foreign institutional investors operating in Belgium.

Source: NBB.

The volume of these inflows has thus been dictated by the exchange rate constraint. They were considerable at the beginning of the 1980s, but declined progressively towards the end of the decade. As from 1990, the Treasury has been able to make repayments and thus reduce its foreign currency denominated debt, except in 1993, a year marked by extreme tensions on the foreign exchange market.

This foreign currency borrowing has enabled foreign investors to play a role in the financing of the Belgian government (Table 3). Non-residents are, however, concentrated in the foreign currency segment of the debt, holding more than 85% at end-1998. At that date over 80% of franc-denominated debt was placed with Belgian financial intermediaries (banks and institutional investors). In this second segment, the share held by non-residents has actually risen, from 4% in 1980 to 11.3% in 1998, but this increase has been mainly at the expense of the share held by non-financial residents. It is largely the result of the recycling in Belgium of franc-denominated funds invested by Belgian individuals with Luxembourg or Dutch banks for the fiscal reasons mentioned above.

The introduction of the euro has obviously altered this situation and, in particular, eliminated the balance of payments constraint. This will, however, give way to a new imperative, namely that of ensuring an environment in which Belgian investors and borrowers alike will be able to benefit from the best possible investment and financing conditions within EMU, and which will at the same time make it possible to preserve the source of revenue and activity which the existence of domestic financial markets and intermediaries represents for the national economy.

In this context, attention will no longer focus on investments by individuals. They will certainly continue to diversify their assets, but the introduction of the euro should above all prolong and reinforce a movement which, as just seen, has already been well under way for a number of years.

The real change will take effect at the level of financial intermediaries. Hitherto their role in diversification operations has been mainly indirect, consisting in the advice and services provided to their private investor clientele. In operations for their own account, banks have been guided first and foremost by the (legitimate) concern of balancing their net Belgian franc and foreign currency positions. This does not imply that they have been keeping their distance from the foreign exchange market. On the contrary, to satisfy a Belgian corporate clientele which depends largely on foreign markets for its business, Belgian banks have had to conduct a considerable volume of foreign exchange operations, both spot and forward. They have also accumulated a large amount of interbank foreign currency assets and liabilities on their balance sheets. However, these operations offset each other, so that franc-denominated funds raised from individuals have until now, in the absence of a significant euro-Belgian franc market, been almost exclusively devoted to financing Belgian debtors, principally the government.

Table 3
Holding structure of Belgian public debt
(as a percentage of the total)

	1980	1998
Franc-denominated debt		
Credit institutions	67.1	59.3
Institutional investors	5.8	19.1
Other residents	23.0	10.4
Luxembourg	3.1	7.1
Other non-residents	0.9	4.2
Total	100.0	100.0
Foreign currency denominated debt		
Credit institutions	63.7	14.3
Institutional investors	–	–
Other residents	–	–
Luxembourg	–	–
Other non-residents	36.3	85.7
Total	100.0	100.0
Total debt		
Credit institutions	66.9	56.5
Institutional investors	5.5	17.9
Other residents	21.7	9.7
Luxembourg	2.9	6.6
Other non-residents	2.9	9.3
Total	100.0	100.0

Source: NBB.

It is this feature which is changing with the advent of EMU. Banks will no longer have to limit the use of their deposits, now denominated in euros, to purchasing domestic assets. Similarly, insurance companies and pension funds will see a relaxation of the constraint imposed by the obligation to maintain a fairly strict balance in the currency composition of their assets and liabilities. Likewise, UCITS specialised in Belgian franc-denominated investments will be able to widen their investment policy to cover the whole of the euro area. Finally, Dutch and Luxembourg banks which used to recycle in Belgium franc-denominated deposits received from Belgian individuals will obviously be able to invest these funds, now denominated in euros, on other markets.

This redeployment will have far-reaching repercussions for the two big borrowing sectors in the Belgian economy, the government and the corporate sector. The two main securities markets available to these sectors, the government securities market and the stock market,[1] will need to adapt.

[1] The third potential market, that of corporate fixed income securities, is still very underdeveloped in Belgium. The introduction of the euro will no doubt be a significant expansionary factor. This third market will not, however, be analysed here as it raises issues very different from those concerning the future potential of the more mature government securities market and Brussels Stock Exchange.

3. Government securities market

Given its high degree of standardisation and its strong dependence on Belgian credit institutions, the government securities market is likely to be the most rapidly affected by the introduction of the euro. In particular, dematerialised securities issued by the Belgian Treasury, either long-term (linear bonds or OLOs) or short-term (treasury certificates), will enter into direct competition with the euro-denominated securities offered by the other EMU member countries.

After only a few months of EMU, there has already been a significant change in the structure of OLO holdings (Table 4). Whereas the rest of the world's share had fluctuated during the previous three years at around 10%, it climbed to almost 20% in the first six months of this year. It is mainly Belgian credit institutions that have reduced their portfolios, as other Belgian holders do not seem to have restructured to the same extent as yet. On the treasury certificate market, the trend towards diversification had started earlier, the rest of the world having already increased its share of the market from 32.2% to 43.5% between end-1996 and end-1998.

Table 4

Recent development of the holding structure of linear bonds and treasury certificates

As a percentage of the total, at end of period

	1996	1998	1999	
			March	June
Linear bonds (OLOs)				
Belgium	87.4	55.3	12.6	13.9
of which: Belgian credit institutions	91.9	51.0	8.1	13.0
Other holders	83.9	27.5	16.1	n.a.
Rest of the world	81.1	30.3	18.9	n.a.
of which: EMU*	59.9	28.6	n.a.	2.2
Other countries	61.6	30.1	n.a.	5.9
Total	100.0	100.0	100.0	100.0
Treasury certificates				
Belgium	67.8	48.8	32.2	23.5
of which: Belgian credit institutions	56.5	45.6	43.5	21.1
Other holders	59.5	17.3	40.5	n.a.
Rest of the world	56.7	15.3	43.3	n.a.
of which: EMU*	50.5	10.6	n.a.	17.1
Other countries	41.2	11.1	n.a.	22.2
Total	100.0	100.0	100.0	100.0

* Excluding Belgium.

Source: NBB.

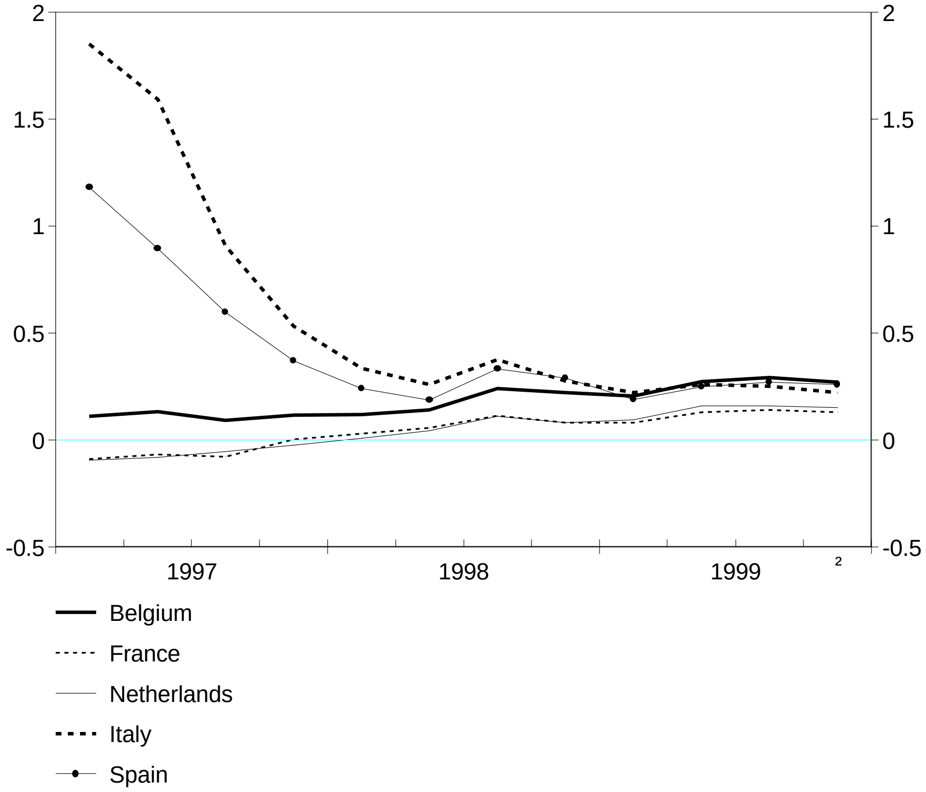
It has to be noted that these figures do not take into account changes of ownership which are solely due to repurchase agreements. These repos are extensively used by Belgian banks as a convenient technique to cover net borrowings of bonds in euros from abroad. While they result in a transfer of Belgian government securities holdings from Belgium to the rest of the world, such operations are not motivated by the economic purpose of portfolio diversification. By focusing on this economic concept, Table 4 underestimates the amount of Belgian government securities legally in the hands of the rest of the world. This restriction strengthens the significance of the changes in the ownership of OLOs recorded in Table 4.

This quite naturally raises the question of the terms on which the Treasury has been able to attract foreign investors. A change in holding structure does not indicate whether or not it was necessary to increase rates, be it to counter the declining interest of traditional investors or to attract new ones.

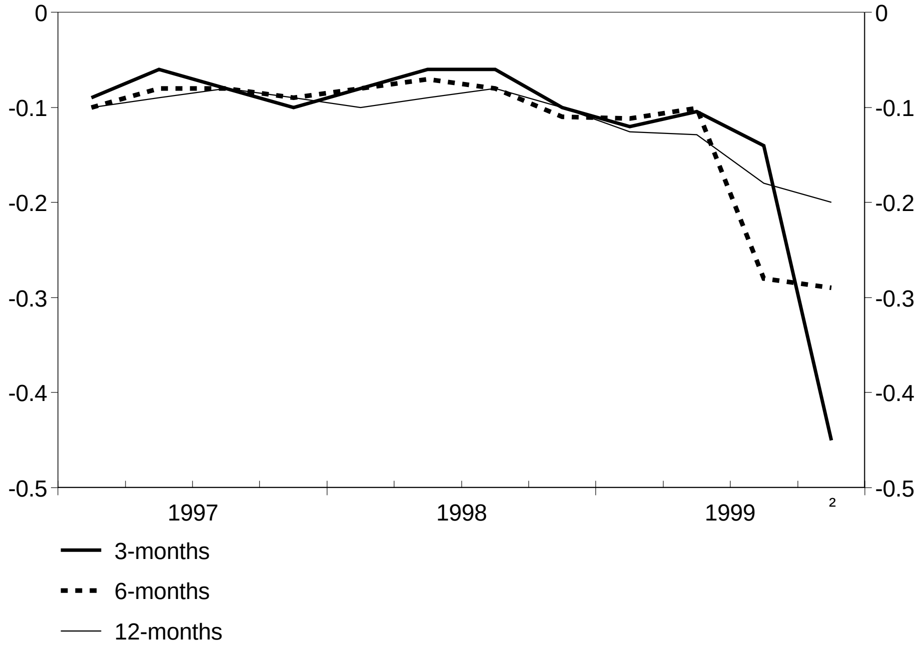
Chart 1

RECENT EVOLUTION IN INTEREST RATE CONDITIONS ON THE BELGIAN GOVERNMENT DEBT

INTEREST RATE DIFFERENTIALS WITH TEN YEAR GERMAN BONDS



INTEREST RATE DIFFERENTIALS BETWEEN BELGIAN TREASURY CERTIFICATES AND INTERBANK DEPOSITS [1]



Source: NBB.
1. Bibor until 1998, Euribor thereafter.
2. Average October and November.

Here too a distinction must be made between short- and long-term securities. On the bond market, the spread between the 10-year Belgian OLO and the 10-year German bund, the market benchmark, has widened somewhat further in 1999, prolonging the trend already observed the year before (upper panel of Chart 1). Belgium is not an isolated case, since there has been a similar widening for the other euro area members, including countries like Italy or Spain which had seen a narrowing of the differential prior to joining EMU.

On the money market, the main yardstick is Euribor, which has replaced Bibor and its equivalents in other countries that have joined the euro area. Relative to Bibor/Euribor, the negative spread on treasury certificates has widened. Taking the average for three-, six- and 12-month instruments, the differential increased from an average of eight basis points for 1997 and the first three quarters of 1998 to 11 basis points during the following three quarters. The spread even widened sharply in the course of the third and fourth quarters, rising to 20 basis points for 12-month certificates, 29 basis points for 6-month certificates and 45 basis points for 3-month certificates (lower panel of Chart 1). These last two developments are, however, strongly influenced by the approach of the year 2000. Given the technological uncertainties surrounding the date change, credit institutions are increasingly anxious to arrange easy access to liquidity at year-end and are therefore shunning interbank deposits maturing after 1 January, whose rates are thus being pushed up, and turning to treasury certificates, which can be mobilised at any time via repos.

However, even after correction of this exceptional factor, it does seem that since the introduction of the euro the Belgian Treasury has enjoyed somewhat more favourable conditions for its short-term borrowing, while the reverse seems to be proving true for long-term issues.

The causes of this divergence are to be found in the two major factors that continue to differentiate the government securities markets of the EMU member countries, namely credit risk and liquidity.

These two major criteria make scarcely any difference in the case of treasury certificates. First, all EMU member countries have the highest rating for their short-term euro-denominated debt. Second, with the advent of a uniform money market and widespread use of repos in the euro area, liquidity differences are now virtually irrelevant as regards short-term government securities. Moreover, the Belgian government may benefit from a certain rarity advantage in this segment in that a number of EMU countries, in particular Germany, issue hardly any short-term government paper, whereas Belgium is one of the countries with proportionally the greatest presence on this market (Table 5).

Table 5
Structure of euro area government debt at end-1997
As a percentage of the total

	Treasury bills	Variable rate bonds	Fixed rate bonds	Foreign currency debt	Non-marketable debt and other*	Total
Belgium	17	2	71	8	2	100
Austria	1	8	50	20	21	100
Finland	5	0	53	38	4	100
France	7	5	75	0	13	100
Germany	2	2	80	0	16	100
Ireland	3	5	49	26	17	100
Italy	14	26	45	6	9	100
Netherlands	3	0	82	0	15	100
Portugal	9	12	34	22	23	100
Spain	28	0	62	9	10	100

* Including non-marketable savings bonds and accounts.

Source: OECD.

The situation is different on the capital market. The spreads between the bund and other EMU long-term government securities vary from one member country to another, and these spreads are correlated with the various countries' ratings.

This relationship can be seen from a rudimentary test whereby ratings, by nature qualitative, are first transformed into quantitative data. To do this, an average is calculated for the ratings awarded by the three main rating agencies – Standard & Poor's, Moody's and Fitch IBCA – after converting them into 1 for the highest rating (AAA or Aaa), 2 for the next rating (AA+ or Aa1) and so on (Table 6). A clear classification similarity appears between the average thus obtained and the spreads vis-à-vis the bund. This is confirmed by a simple linear regression between these two variables (first line in Table 7). The relationship is statistically significant and indicates that a lowering of the average rating by one notch is accompanied by a widening of the differential by about 4 basis points.

Table 6

Credit ratings for euro-denominated government bonds and long-term interest rate spread vis-à-vis Germany in the euro area in 1999

	Standard & Poor's	Moody's	Fitch IBCA	Credit rating[1] (average grade)	Long-term interest rate spread[2] (vis-à-vis Germany, in basis points)
France	AAA	Aaa	AAA	1.0	11
Netherlands	AAA	Aaa	AAA	1.0	13
Luxembourg	AAA	Aaa	AAA	1.0	15
Austria	AAA	Aaa	AAA	1.0	17
Ireland	AA+	Aaa	AAA	1.3	20
Finland	AA+	Aaa	AAA	1.3	22
Spain	AA+	Aa2	AA+	2.3	23
Belgium	AA+	Aa1	AA–	2.7	25
Portugal	AA	Aa2	AA	3.0	26
Italy	AA	Aa3	AA–	3.7	24

[1] Data on credit ratings are averages of the most recent ratings from Standard & Poor's, Moody's and Fitch IBCA (with a value of 1.0 for the highest rating, 2.0 for the next, and so on). [2] Data on the long-term interest rate spread vis-à-vis Germany are averages of monthly data over the period January–August 1999.

The hypotheses underlying this regression are, first, that the three rating agencies have the same weighting in the eyes of market participants and, second, that the gap between AAA and AA+ has the same significance in credit risk terms as that between AA+ and AA or between AA and AA–.

One risk factor that is directly quantifiable is the level of public debt. This is one of the main elements taken into consideration by the markets in evaluating sovereign risk, and its psychological importance has been further emphasised by its inclusion in the criteria for both entry into EMU and compliance with the growth and stability pact.

Lines 2 to 5 in Table 7 attempt to measure the link between the long-term interest rate differential vis-à-vis Germany and the debt ratio of the 11 EMU member countries during the period 1992–99. The combination of series by country and by year (panel data) enables the number of variables to be increased, but introduces the important assumption that the reactions of interest rate differentials to changes in the debt do not differ too greatly from country to country.

Integrating the public debt criterion immediately raises certain conceptual problems. Taking the debt ratio as a stock (line 2) disadvantages countries with a high percentage of debt at the start of the period. Conversely, using only the change in the debt ratio (line 3) disadvantages countries that start from a lower level of debt and will thus find it more difficult to reduce it further.

Table 7

Average response of euro area countries' long-term interest rate spread vis-à-vis Germany to different explanatory variables[1]

Constant	Credit rating[2]	Debt ratio[3]	Change in debt ratio[2]	$\overline{R^2}$
0.1179	0.0427			0.66
(5.2882)	(3.9571)			
0.3923		0.0099		0.05
(0.9556)		(1.8899)		
1.0018			0.1145	0.15
(6.4703)			(3.4247)	
0.1415		0.0121	0.1204	0.23
(0.3979)		(2.6611)	(3.7554)	
		0.0138	0.1209	0.23
		(7.3024)	(3.7981)	

[1] Data in parentheses are t-statistics. [2] Annual data for the first regression relate to 1999 only. [3] Annual data for the other regression relate to the period 1992–99.

Source: NBB.

The best results are obtained by combining the interest rate level and change (line 4 with a constant different from zero and line 5 with a constant equal to zero). However, the explanatory power of these two regressions is fairly low ($R^2 = 0.23$). The interest rate differential is therefore much less closely linked to the public debt than to country ratings. This might indicate either that the market relies heavily on the rating agencies in evaluating sovereign risk or that it uses an implicit model similar to that of the rating agencies in doing so.

In any event, credit risk alone cannot fully explain the long-term interest rate differential between Germany and the other EMU member countries. This differential exists even for countries such as France, the Netherlands, Austria and Luxembourg which have precisely the same ratings as Germany.

These divergences are accounted for by the second factor which differentiates European government securities markets, namely the degree of liquidity. A market is said to be liquid when participants can rapidly execute major transactions on it without exerting a significant impact on prices. Although this definition is commonly accepted, there is much less of a consensus as to the best indicator of a market's liquidity.

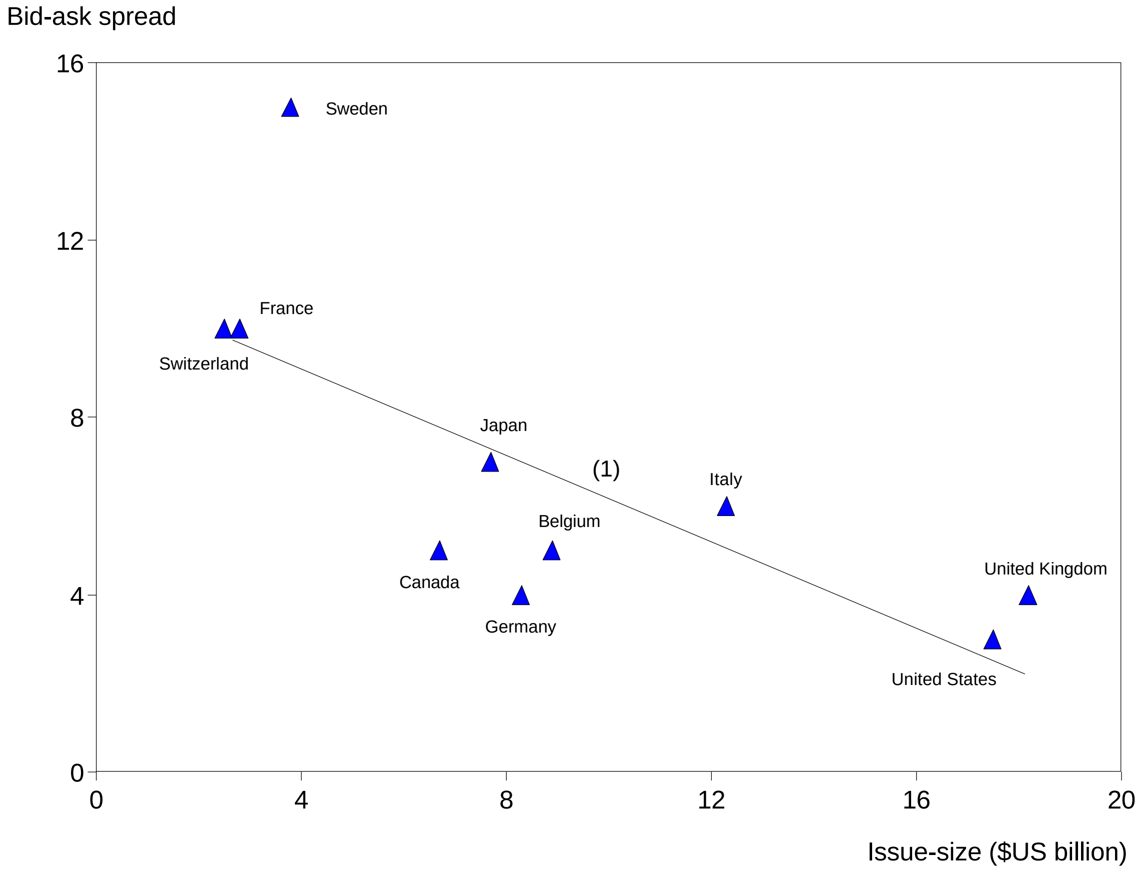
The volume of issuance on the primary market is certainly an important element. Moreover, an international comparison by the BIS tends to show that there is an inverse relationship between the size of issues and the width of secondary market bid-ask spreads on 10-year benchmark bonds (Chart 2). In principle, this should tend to favour the large countries. However, the volume of bond issuance is also a function of the degree of indebtedness, the percentage of debt financed on the securities market, issuance and repayment techniques, and the maturity distribution. These various criteria explain, in particular, why Belgium issues, in proportion to its size, fairly large amounts of its benchmark bonds, with a bid-ask spread of around 5 basis points.

A second measure of liquidity is activity on the secondary market. It is, however, difficult to collect precise data in this area. While some markets are completely centralised, others operate with a number of clearing systems. Some countries cannot eliminate double-counting, or they incorporate repos in their statistics. The most efficient secondary markets seem to be those which can rely on the presence of a sizable futures market. In this respect, the bund market has a clear advantage due to the very high volume of trading in euro bund futures on Eurex. The volume of French OAT futures on MATIF or Italian BTP futures on LIFFE is much smaller. In Belgium, Belfox stopped OLO futures trading during the second half of 1998.

Finally, it is important to note that the choice of a specific maturity is a far from neutral factor in the evaluation of market liquidity. The maturity most commonly used is the 10-year benchmark. As shown in Chart 3, it is precisely for this maturity that the spread between Belgian or French and

Chart 2

ISSUE SIZE AND BID-ASK SPREAD FOR ON-THE-RUN 10-YEAR GOVERNMENT BONDS



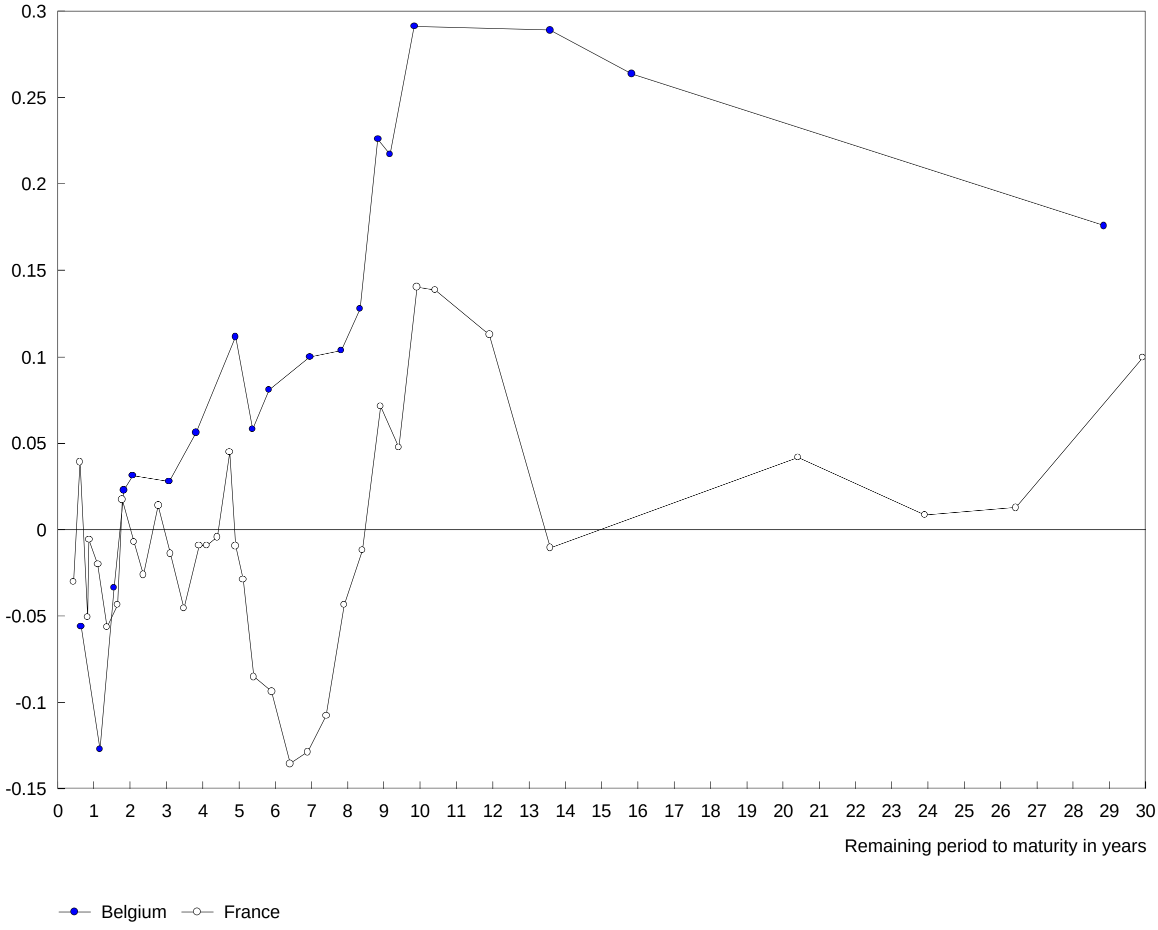
Sources: OECD, BIS.
1. Simple OLS regression yielding the following: Bid-ask spread = 11.2 - 0.5 * issue size.

German government bonds is the greatest.[2] Although the bund has the lowest rates for maturities between nine and 12 years as well as for the 30-year maturity, it is the French OAT which constitutes the benchmark for maturities from five to eight years, while, for other maturities, the rates on these two categories of securities are very close.

Chart 3

YIELD DIFFERENTIAL OF FRENCH AND BELGIAN GOVERNMENT SECURITIES VIS-A-VIS GERMAN GOVERNMENT SECURITIES

(As at 1 June 1999-in percentages)



Source: NBB.

2 In order to correct the distortions which could result from slight differences in the exact maturities of bonds, Belgian and French bond yields were compared with theoretical yields on German bonds of the same maturity calculated by interpolating the two German bonds with the closest maturities.

In the case of the Belgian OLO, the differential significantly exceeds 10 basis points only for maturities greater than eight years. There is even a negative spread on the shortest maturities (18 months and less). It would obviously be risky to draw a general conclusion from this given the more erratic movement of rates in this segment of the yield curve (the bund-OAT spread also fluctuates somewhat for the shortest maturities). This particular structure does at least not contradict the above-mentioned hypothesis that the Belgian Treasury may benefit from proportionally more favourable conditions for its short-term bonds.

The Belgian Treasury did actually take advantage of this in April 1999 when it issued a new line of floating rate OLOs benchmarked on three-month Euribor. It was the first sovereign issue of this type in the euro market. It allowed the Treasury to benefit from a slightly more favourable funding cost than for a three-year fixed rate OLO swapped into floating.

In view of the importance of liquidity in the strategic positioning of the various domestic government securities markets within the euro area, the Belgian Treasury has taken a series of initiatives to facilitate the placement of its securities with a broader range of investors.

In order to speed up the introduction of its new 10-year benchmark lines on the primary market, the Treasury has decided to offer the first tranche of issues at that maturity through syndicates in order to create a sufficient stock from the outset; the following tranches will, as usual, be auctioned.

To stimulate the secondary market, the Treasury has substantially increased the number of non-resident intermediaries among primary dealers. This has made it possible both to gain better access to international customers and to make up for the reduction in the number of domestic primary dealers due to the ongoing restructuring of the Belgian banking sector. The Treasury has also created a new category of agents on this market – recognised dealers – whose role is to place debt securities in specific targeted foreign markets.

These various measures bear witness to the at times difficult trade-offs which the Treasury has to make. As a Belgian government entity, it cannot be insensitive to its contribution, via the public debt, to maintaining intermediation, market activity and financial management in Belgium. At the same time, as a borrower, it is duty-bound to make the arrangements necessary to obtain the best financing conditions, if necessary by increasing its reliance on foreign intermediaries.

4. Stock market

While the various government securities markets in the euro area show a high degree of standardisation, the same is not true of the stock markets, as accounting standards, company law and corporate tax regimes continue to differ greatly from country to country. These legal and institutional divergences are accompanied by more economic characteristics, such as the size and reputation of the companies listed, their sectoral distribution and their shareholder structure. It is important to take these characteristics into account when evaluating the development prospects for the various national stock markets following the introduction of the euro.

Compared with those of its three main neighbours, Belgium’s stock market appears quite small, whether judged by the number of companies listed, its capitalisation or the volume of capital raised (Table 8).

A second major characteristic is the relative absence of very large companies, the famous blue chips which often serve as a stock market’s showcase. The degree of concentration, measured by the relative share of the 5% of companies with the largest capitalisation, is only 56.5% on the Brussels Stock Exchange while it is close to 70% on the Paris Stock Exchange and well above that figure in Amsterdam and Frankfurt.

This situation reflects the size of companies in Belgium, which are mainly small and medium-sized companies with a very small number of big multinationals. Another indicator of this specific structure can be found in the proportion of issues of unlisted equities. Between 1993 and 1998, out of an annual average total of €8.1 billion of cash raised through equity issues in Belgium, €6.7 billion or 83% was in the form of private issues by essentially family-based entities.

Table 8
Companies listed on stock exchanges

	Number of listed companies (end-1998)	Market capitalisation (billions of euros at end-1998)	Funds raised in 1997 and 1998 (billions of euros)	Concentration of market value[1] (end-1998)
National stock exchanges[2]				
Brussels	146	210.4	4.0	56.5
Frankfurt	741	930.8	28.9	77.8
Paris	914	837.1	44.8	68.6
Amsterdam	212	512.4	52.5	73.3
Total	2,013	2,490.6	130.1	
Brussels as a percentage of total	7.3	8.4	3.1	
Euro-NM				
Brussels	8	0.2	0.1	
Frankfurt	63	26.1	3.1	
Paris	81	4.2	0.9	
Amsterdam	13	1.0	0.2	
Total	165	31.4	4.2	
Brussels as a percentage of total	4.8	0.8	1.8	
EASDAQ				
Belgian shares	9	3.4	0.3	
Other shares	30	9.7	1.3	
Total	39	13.1	1.6	
Belgian shares as a percentage of total	23.1	25.8	20.1	

[1] Share of the 5% of most highly capitalised listed companies. [2] Primary and parallel markets, domestic stocks.

Sources: International Federation of Stock Exchanges; EASDAQ; Euro-NM.

This market segment might offer broad development possibilities for venture capital or initial public offerings, if necessary via markets specialised in growth stocks. There are actually two markets of this type accessible to Belgian companies. The first is Euro-NM Brussels, which is the Belgian compartment of a broader market, the fruit of a joint initiative of the Frankfurt, Paris, Amsterdam and Brussels exchanges. The second is EASDAQ, modelled on NASDAQ and based in Brussels. The latter feature is very probably the reason why Belgian companies have a proportionally greater presence on EASDAQ than on Euro-NM Brussels. However, if these two new specialised markets are combined, the relative importance of Belgium compared with its three large neighbours is fairly similar for the specialised and for the leading stock markets.

On the secondary market, Belgium also has two major characteristics that set it apart from its partners. The first – the extensive foreign presence – has already been highlighted in Table 2. The proportion of listed Belgian equities held by the rest of the world rose from some 13% in 1980 to around 31% in 1998. These purchases represent not only portfolio investments but, in a large number of cases, direct investments following mergers or acquisitions.

These operations have contributed to accentuating the second major characteristic of the secondary market on the Brussels Stock Exchange, namely the very high percentage of closely held equity, which at nearly 55% (Table 9) is appreciably higher than on most other stock exchanges. The bulk of Belgian companies are integrated into holding structures and have a single major shareholder. Thus, on average, the principal direct shareholding for listed Belgian companies is 41%. As a result, the so-called "float", i.e. the proportion of the shares which really sustain activity on the secondary market, is rather small.

Table 9

Holding structure of shares listed on the primary market on the Brussels Stock Exchange

	October 1990	January 1996	August 1998*
Number of listed companies	159	139	128
Stock exchange capitalisation (in billions of euros)	58.4	82.5	165.3
Average percentage closely held	55.0%	53.8%	54.2%
Average percentage of largest direct participation	31.8%	34.2%	40.8%
Average percentage of largest direct and indirect participation	40.9%	41.7%	44.7%

* Excluding five big companies which terminated their stock exchange listing during the second half of 1998.

Source: BBL/ING.

To summarise, the smallness of the Belgian market, the relative absence of big name companies and the fairly high percentage of closely held equities are so many variables likely to impact on the process of integrating the Belgian stock market into the euro area.

Even less so than in the case of the public debt, there is at present a lack of volume data that would make it possible at this stage to measure any changes in the Belgian shareholder structure that might have been induced by the advent of EMU. It is therefore mainly price data that have to be relied on. Stock prices are, however, a more difficult variable to interpret than interest rates on government securities. Equities are a much more heterogeneous type of security than bonds, with their prices very largely dependent on individual factors specific to each issuer.

These specific factors have not prevented a close correlation between the leading European stock markets in the run-up to EMU (upper panel of Chart 4). The German (CDAX) and French (SBF 250) stock indices have moved in unison and have also closely followed the general Euro STOXX index. The Belgian index too has been aligned with the overall trend.

Over the past few months, the performance of the various markets has become much more disparate. While the Euro STOXX index and the general index of the Paris Stock Exchange (SBF 250) have continued to move in unison, the Belgian and German indices have gradually diverged. This divergence emerged at the end of 1998 in the case of Germany, where the recovery in stock prices after the third-quarter correction was only very gradual. In Belgium, prices fell sharply during the first half of 1999 in contrast to the trend observed on other markets.

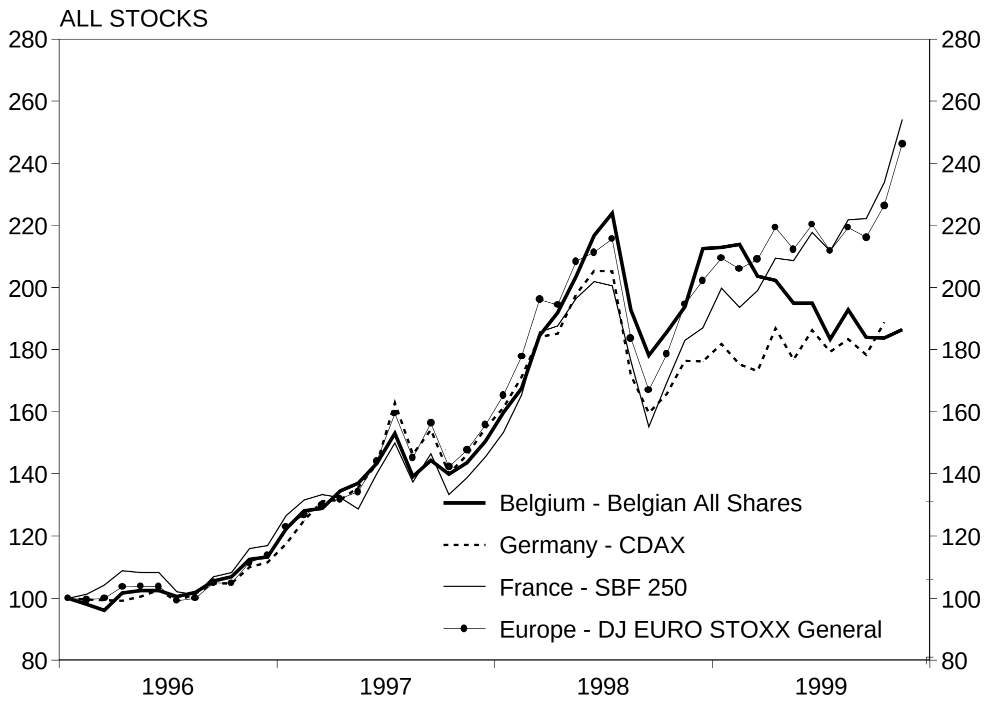
One possible initial explanation is business cycle asymmetry. The slowness of the recovery in Germany compared with a number of other European countries is probably one of the causes of the sluggishness of the Frankfurt market.

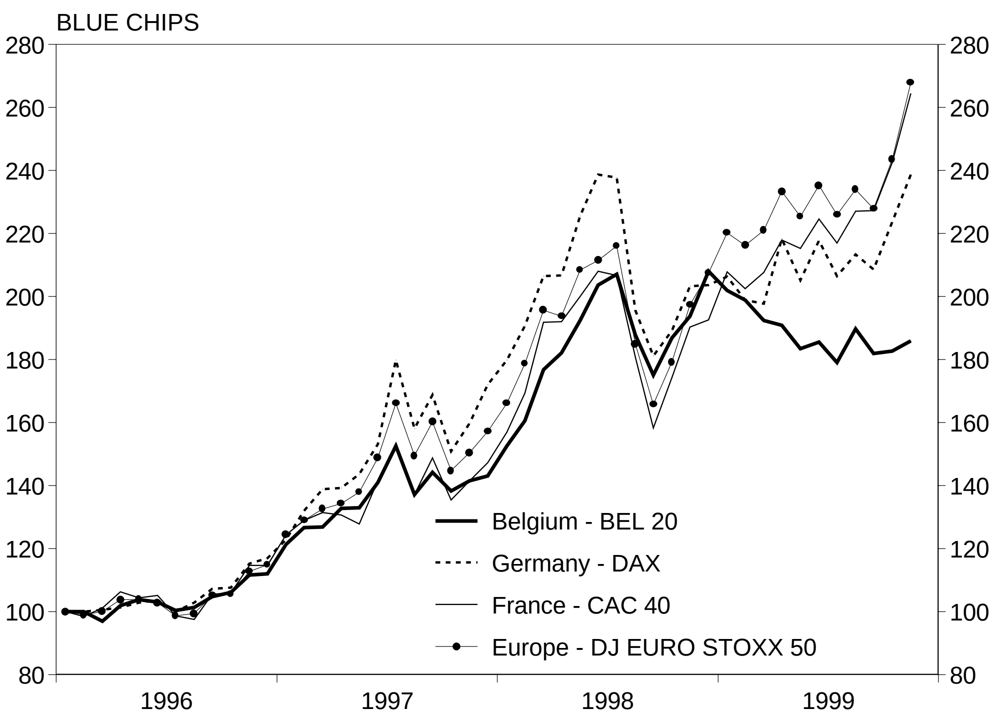
This argument seems, on the other hand, much less applicable to Belgium, which has not really lagged behind the business cycle compared with the majority of its European partners. On the contrary, over the past few months various market participants and financial analysts have been highlighting the fact that for a number of years the Belgian economic indicator has been a leading indicator of changes in the growth of the euro area as a whole.[3]

[3] See, for example, the article by Christopher Rhoads in *The Wall Street Journal* of 14 July 1999.

STOCK EXCHANGE PRICES

(End of period, January 1996 = 100)





Sources: BIS, national stock exchanges.

The atypical movement of stock prices in Belgium in recent months might also have more structural causes. In 1998, the Brussels Stock Exchange rose more strongly than the other European stock exchanges. It was also less affected by the decline in prices during the third quarter, so that at year-end it was at a proportionally higher level than its counterparts. One of the reasons put forward for this good performance is the number of mergers and acquisitions on the Belgian market recently, in particular in the financial sector. These operations might have been accompanied by speculative position-taking which would have pushed prices upwards. In this context, the movement observed since the beginning of 1999 would basically constitute a correction.

It should, however, be mentioned that there have also been numerous mergers and acquisitions abroad. These restructuring operations have, moreover, continued in 1999, again both in Belgium and elsewhere.

In addition, this hypothesis of the correction of a previous overvaluation does not seem to be borne out by movements in indices for blue chips, which in Belgium were particularly affected by mergers and acquisitions. For the period 1996–98 as a whole, the rise in the BEL20 was not very different from that in the corresponding indices in Germany (CDAX), France (CAC40) and the euro area as a whole (Euro STOXX 50) (lower panel of Chart 4). Admittedly, as was the case for the general index, the BEL20 recorded a smaller correction than the other countries' indices in the second half of 1998. However, this movement only offset the slower increase in prices registered in 1997. Rebased to 100 in January 1996, the BEL20, DAX, CAC40 and Euro STOXX 50 benchmark indices were all at very similar levels at the end of 1998.

This parallelism makes the divergence observed since the beginning of 1999 all the more striking. Whereas the Euro STOXX 50, the CAC40 and, to a lesser extent, the DAX have trended upwards, the BEL20 fell by nearly 14% between end-December 1998 and end-July 1999.

This brings us to the role which the introduction of the euro might have played in recent movements in stock exchange prices. The existence of the single currency allows investors to broaden their investment horizons without exposing themselves to exchange rate risk any longer. Country diversification is replaced by sectoral diversification. The latter should particularly benefit major stocks, as it is stocks of big companies that are the most widely known and often have the most liquid markets. Information on them is generally more abundant and more readily available.

As mentioned above, the Belgian stock market has only a small number of big companies. Diversification by Belgian investors into the leading stocks of other European countries is therefore unlikely to be offset by an opposite flow of the same magnitude due to the relative dearth of such equities on the Belgian market. By way of an example, the Euro STOXX 50 contains only two Belgian stocks (Fortis and Electrabel).

Another sign of this concentration of investors' interest in big companies' stocks is the movement of the Euro STOXX 50, which, particularly over the last few months, has risen faster than most national stock indices. This discrepancy in price movements for leading stocks only and for the market as a whole seems to be confirmed by Chart 5. Both for Europe as a whole and for Germany and, to a lesser extent, France, the index of blue-chip equities has risen more than the general index, especially during the most recent period. Belgium, however, has been an exception to this rule. The asymmetrical diversification referred to above has affected the prices of leading Belgian securities all the more because a substantial proportion of them are closely held (Table 9). The fairly small floating segment makes the price of these equities more sensitive to changes in the structure of investment portfolios.

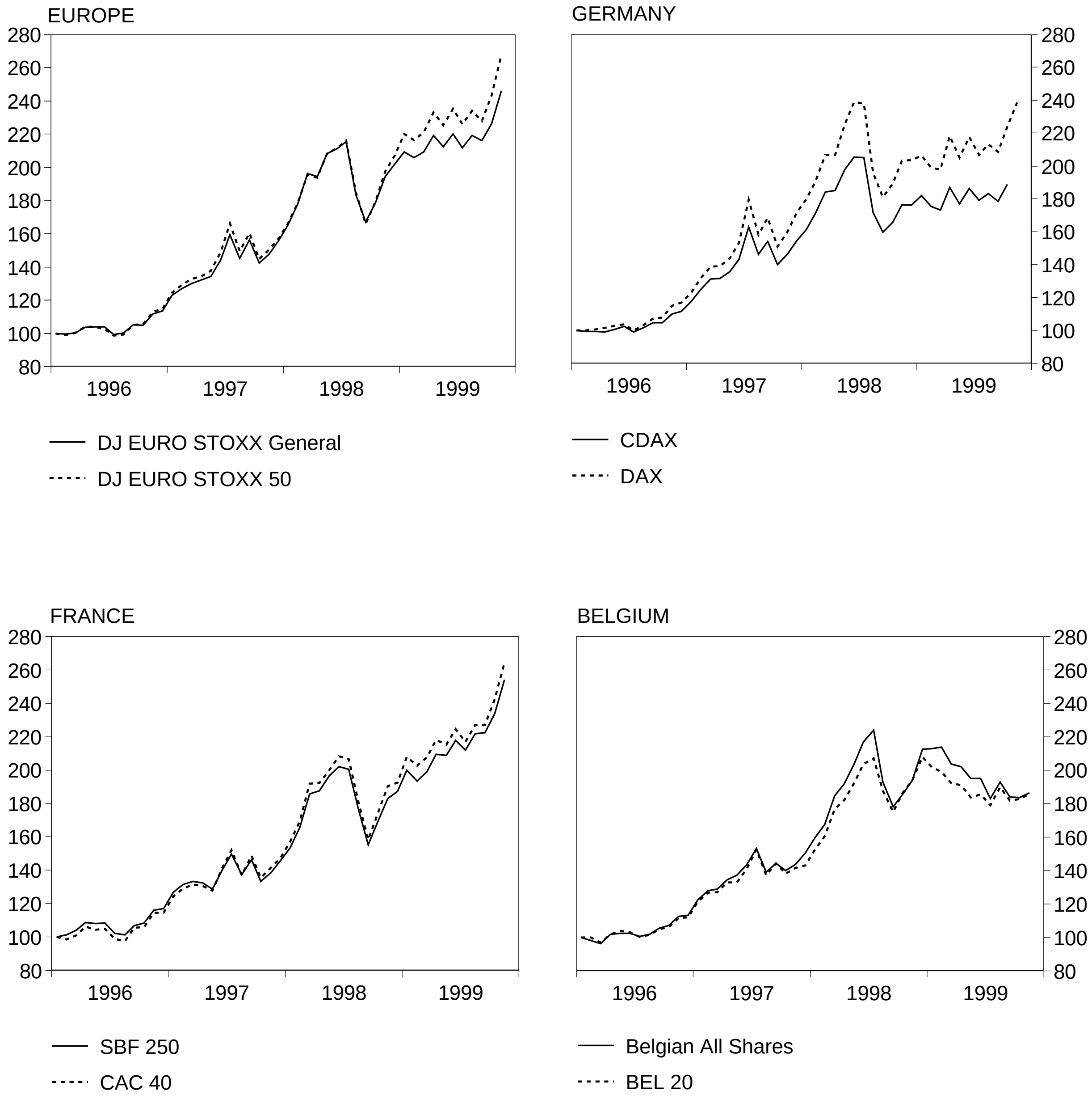
It should not be concluded from this that these movements are irreversible. The effect of portfolio restructurings on prices will no doubt be temporary; in an efficient market, there is basically no justification for a systematic undervaluation of shares on a particular market. Nonetheless, the Brussels Stock Exchange has very few blue-chip equities to speak of and, moreover, the large portion that is closely held tends to limit trading in them.

To adapt itself to this new environment, the Brussels Stock Exchange needs to adopt an ambitious restructuring programme. This programme has three main dimensions, along the lines of those adopted by other stock exchanges.

Chart 5

STOCK EXCHANGE PRICES:
COMPARISON OF ALL STOCKS AND BLUE CHIPS PRICES

(End of period, January 1996 = 100)



Sources: BIS, national stock exchanges.

The first is the vertical integration, or merger, between the Brussels Stock Exchange, the derivatives market (Belfox) and the Securities Deposit and Clearing Office (CIK). These three entities were merged into the Brussels Exchange (BXS) at the beginning of 1999.

The second trend is that of demutualisation. The BXS has been set up as a public limited company whose board is partly made up of independent directors. This structure protects the exchange against the risk of a fluctuation in capital, inherent in a cooperative setup, and allows a subsequent offering of capital to third parties, or even a listing.

The third trend is the establishment of ties between European exchanges. The Brussels Stock Exchange became involved in this process at a very early stage, first by participating in the founding of Euro-NM (see above) and second by concluding a cross-membership agreement with the two other Benelux exchanges in 1998. Finally, the Brussels Stock Exchange is party to the decision taken recently by eight European exchanges to organise a common listing of leading European stocks.

It would, however, be wrong to concentrate exclusively on the locational aspect of stock markets. The new electronic trading systems are in any case likely to greatly reduce the relevance of geography. The important thing is not the physical location of the quotation and trade processing systems. True added value for an economy lies in intermediation, brokerage and particularly financial and market analysis. Much more than the existence of a stock exchange, maintaining and extending a market requires the presence of institutional investors, venture capitalists and M&A consultancy and financing specialists.

In this respect, the handicap of the small number of very big companies listed on the Brussels Stock Exchange appears to be relative since the processing of transactions involving leading European equities is eventually likely to become centralised on one dominant major exchange. The challenge is therefore to develop expertise that would make it possible to provide a broad range of financial services to companies of comparable size to those which make up the major part of the Belgian corporate structure.

5. Conclusions

Belgian individuals certainly did not wait for the introduction of the euro before purchasing financial assets abroad. Tax considerations in addition to the desire to diversify and the quest for higher returns encouraged investors to invest in foreign currencies.

These capital movements were a significant constraint on the balance of payments, given Belgium's fixed exchange rate objective. To counterbalance these outflows, the current account surplus had to be supplemented with offsetting capital inflows, which were of two main types. The first category was direct investments, which were reflected in an increase in the holding of Belgian equities by non-residents. The second consisted of government securities in foreign currency, issued principally abroad, unlike franc-denominated public debt, which was almost exclusively placed in the domestic market.

The two big Belgian securities markets, the stock market and the government securities market, have thus been partly shaped by the exchange rate constraint. Although this has now been eliminated by the advent of EMU, a new requirement has taken its place: ensuring the harmonious incorporation of Belgian markets into the euro area or, more specifically, reconciling the double objective of guaranteeing Belgian investors and borrowers the best financing conditions and preserving, in Belgium, the source of returns and activity provided by domestic markets and intermediaries.

As a government entity and principal borrower on the market, the Treasury is particularly affected by this trade-off. A somewhat different trade-off arises with short- and long-term government securities. On the treasury certificate market, the Belgian Treasury benefits from a certain rarity factor in view of the insignificance of short-term public debt in most of the other euro area countries. With this advantage, it has been possible to slightly improve financing conditions owing to the advent of EMU, particularly since liquidity and credit risk are of little importance for this end of the maturity spectrum.

The same cannot be said for the long end, where the two criteria just mentioned are of major importance. It is on 10-year maturities, the bond markets' benchmark, that these two variables have had the most marked effects. The spreads between bunds and other euro area government paper (including Belgian OLOs) are highest for 10-year bonds and have, moreover, tended to increase over the last two years. A first possible measure for the Treasury is to seek out certain niches (floating rate instruments, issues at other maturities, etc.). A second is to further open up the market to foreign investors, which leads back to the trade-off between improving financing conditions and promoting financial activity in Belgium.

On the stock market, securities are evidently more heterogeneous. The challenge posed by integration into the euro area is therefore presented in different terms. Interpreting recent price movements is also more complex and more hazardous to relate to the introduction of the single currency.

One fact emerges clearly. After varying in unison with European, German and French stock indices from 1996 to 1998, Belgian indices diverged very markedly during the first half of 1999. Economic or structural factors alone do not seem able to fully explain this divergence, so that its coinciding with the start of EMU raises questions about the potential role of the euro.

The single currency has encouraged many Belgian investors, both private and institutional, to further diversify their equity portfolios within the euro area. Although it is probable that a readjustment in the opposite direction has also been made by the residents of other European countries, this offsetting movement has been dampened by a lack of major equities on the Brussels Stock Exchange. This would partly explain why Belgian stock indices have moved much less favourably than the corresponding indices elsewhere in the euro area. The asymmetry in diversification operations weighed all the more on the prices of Belgian stocks since a substantial portion is closely held.

These developments are no doubt temporary, as systematic undervaluation is hardly conceivable in an efficient market. However, they do highlight some of the handicaps of the Brussels Stock Exchange in terms of big name stocks and stock liquidity.

Reflections on the future of the Belgian stock market must therefore go beyond the problem of blue chips, which are in any case likely to end up listed on one dominant major stock exchange. They must even go beyond the mere notion of a stock exchange. On the financial markets, added value is not obtained chiefly by maintaining a quotation and trade processing system, but first and foremost from analysis, consultancy and financing, activities which the existence of a local stock exchange can, at best, serve to support and stimulate.

Bibliography

Abraham, J-P and A-F Pirard (1999): "Competition and cooperation among European exchanges: The impact of financial globalisation with special reference to smaller-sized exchanges". *Mimeo* presented at the 1999 Annual Meeting of the European Association of University Teachers in Banking and Finance, Lisbon, September.

Gehrig, T (1998): "Cities and the geography of financial centres". Centre for Economic Policy Research, No. 1894, June.

Lefebvre, O (1999): "Bourses: entre fusions et alliances?" *Revue de la Banque,* pp. 251–4, June.

de Montpellier, L (1999): "La gestion de la dette publique belge dans la perspective de l'euro". *Revue de la Banque*, pp. 192–7, May.

OECD, Economic Department (1999): "Public debt management in WP3 economies: recent developments and policy considerations". *ECO/CPE/WP3*, (99)8, September.

Padoa-Schioppa, T, K Lannoo and D Gros (1998): "Capital markets and EMU: Report of a CEPS Working Party". Center for European Policy Studies.

Rapport 1998 Fonds des Rentes (Belgium).

Revue économique de la Banque Nationale de Belgique (1998): "Le marché financier belge à la veille de l'Union économique et monétaire", pp. 33–67, May.

Roëll, A (1998): "Competition among European Exchanges: Recent Developments", in G Ferrarini (ed.); European Securities Markets: The Investment Services Directive and Beyond, Kluwer Law International, pp. 213–24.

Van Waterschoot, J (1998): "Het aandeelhouderschap na de veldslag". BBL, Financiële berichten No. 2336, November.

The globalisation of financial markets and monetary policy

Hitoshi Sasaki, Satoshi Yamaguchi and Takamasa Hisada[1]

1. Introduction

It has been said that the recent globalisation of financial markets has been driven by increasing capital mobility among countries. Hence, we should consider what kind of impact the globalisation of financial markets has had on the effectiveness of monetary policy.

Looking at the movements of real long-term interest rates in the seven main industrialised countries, G7[2], it would seem that they have been equalising since the late 1980s.[3] And if this phenomenon reflects the equalisation of asset returns because of the global integration of financial markets, we cannot deny the effect in respect of the conduct of monetary policy. This is because monetary policy affects the real economy through various channels and, as one of these channels, the changing of the short-term interest rate by the central bank has an effect on domestic real economic conditions through its influence on the long-term interest rate. If the domestic real long-term interest rate converges to those of other countries, it will be more difficult for monetary policy to affect the long-term interest rate, and consequently its effects on the domestic real economy will be weakened.

Table 1

Difference in real long-term interest rate of each country and mean of the other countries

Sample period	US	JP	DE	UK	FR	IT	CA
1993Q1–1997Q4	2.04	4.52	3.04	4.80	1.33	3.63	1.66
1980Q1–1989Q4	1.14	1.65	1.52	1.76	1.42	1.75	1.53
1990Q1–1997Q4	1.00	1.03	0.97	0.84	0.85	2.11	0.99

Note: Figures represent the standard deviation of the real long-term interest rate of each country minus the mean of the other countries.

However, some previous studies have indicated that world capital markets are still far from perfectly integrated. In fact, monetary policy has seemingly influenced domestic long-term interest rates. In addition, many studies have pointed out that the phenomenon of "home bias", which means the preference of domestic investors to hold domestic assets, has been observed in many countries' markets in spite of globalisation.[4] The observations of home bias indicate that arbitrage transactions

[1] Members of the Policy Research Division, Policy Planning Office, Bank of Japan. The views expressed in this paper are those of the authors and do not necessarily reflect those of the Bank of Japan. The comments of our colleagues from various sections materially improved this paper. Any remaining errors are of course our own.

[2] The United States, Japan, Germany, the United Kingdom, France, Italy and Canada (referred to as MI-7 in the graphs).

[3] The movements of G7 real long-term interest rates are plotted in Chart 1. The standard deviations of differences in the real long-term interest rate of each country and the mean values of other countries' rates are smaller in the 1980s and 1990s than the 1970s, except for some countries and periods (Table 1).

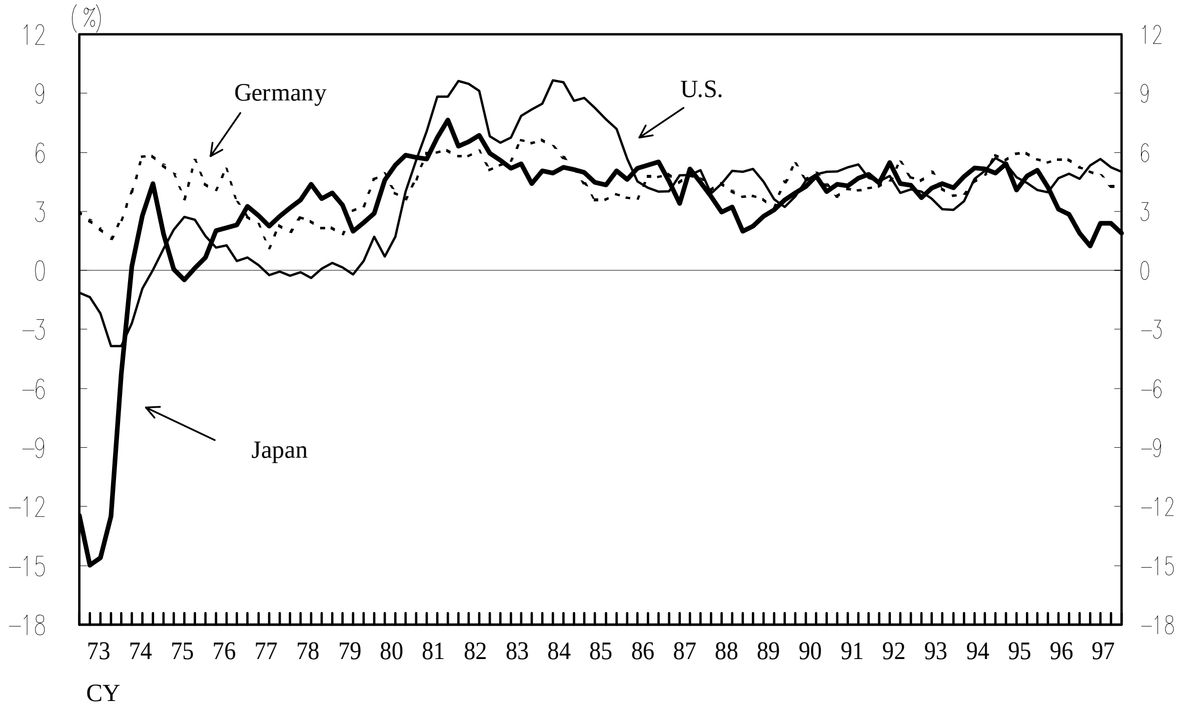
[4] Most of the analyses dealing with home bias focus on the stock markets. For example, French and Poterba (1991) tried to measure investors' portfolios and expected asset returns in three countries, the United States, Japan and the United Kingdom, based on several assumptions. Results indicate that (1) domestic stocks account for the greatest weight in their portfolios: i.e. 94% for the United States, 98% for Japan and 82% for the United Kingdom, and (2) investors in these countries expect the highest returns from their own country's stocks. For example, Japanese investors expect a return of 6.6% from their domestic stock markets, which is about 3 points higher than the figures of 3.2% for US investors and 3.8% for UK investors. Other analyses focusing on home bias include Tesar and Werner (1992), Frankel (1993) and Kang and Stultz (1995).

among countries do not work sufficiently and that various asset returns have not yet perfectly equalised.

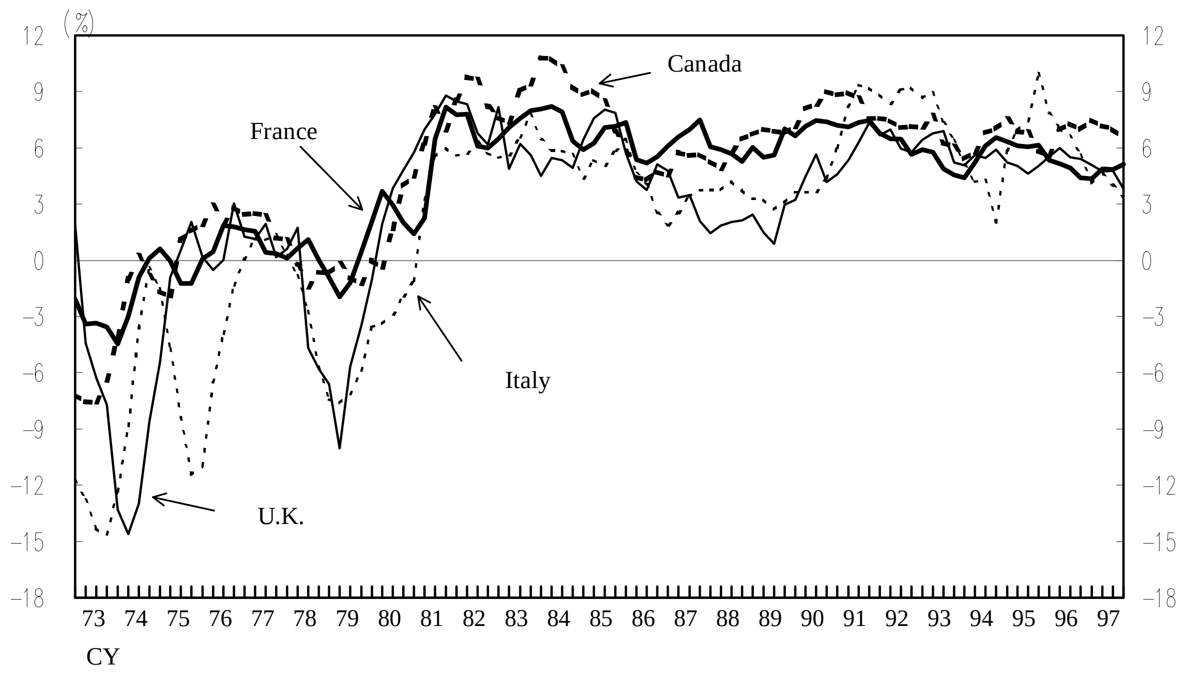
Chart 1

Real Long-Term Interest Rates of MI-7 Countries

(1) U.S., Japan, Germany



(2) U.K., France, Italy, Canada



On the other hand, domestic short-term interest rates are, in general, under the control of the central bank despite the globalisation of financial markets. However, in the case of a global financial shock, the central bank has to conduct, in a sense, bold money market operations to mitigate the impact on domestic financial markets.

In this paper, we look at the determinants of real interest rates in G7 countries and the impact of the global financial crisis in autumn 1998 on Japanese short-term financial markets, in order to examine the effectiveness of monetary policy amid the globalisation of financial markets.[5]

In Section 2, we analyse empirically the determinants of real interest rates in G7 countries and consider the implications. In Section 3, we consider central banks' control of domestic short-term interest rates under the stress of a global financial shock by reviewing the experiences of Japan's short-term financial markets in autumn 1998. The last section concludes the analysis and indicates possible subjects for future study.

2. Determinants of real interest rates in G7 countries

In this section, we analyse the determinants of real long-term interest rates in G7 countries in order to examine the effectiveness of monetary policy amid the globalisation of financial markets.

2.1 Determinants of real interest rates and factors preventing their equalisation

As monetary policy has direct effects on the nominal short-term interest rate, it also has a significant influence on the real short-term interest rate, defined as the difference between the nominal short-term interest rate and the expected rate of inflation (Chart 2). On the other hand, the real long-term interest rate reflects real domestic economic conditions over the long horizon, being affected by the real short-term interest rate.

If world financial and capital markets were perfectly integrated, real interest rates would be equalised internationally through the interest arbitrage transactions across different countries. However, it is generally thought that world real interest rates have not yet been equalised across countries and that differences in real domestic and foreign interest rates remain.[6]

In the portfolio model of two country asset markets, the real interest rate difference is expressed by the sum of the expected change in the real exchange rate and the risk premium which stems from imperfect substitution between domestic and foreign assets (Fukao (1990)). This risk premium should be regarded as a home bias phenomenon in that domestic investors prefer holding domestic rather than foreign assets. There are several reasons why domestic and foreign assets are imperfect substitutes, including exchange rate volatility risk, differences in default risk, institutional aspects such as taxation or regulation of foreign exchange transactions, conventions regarding the payment of principal and interest, and cash transfers.[7]

---

5 Details of data properties and sources are described in the Appendix.

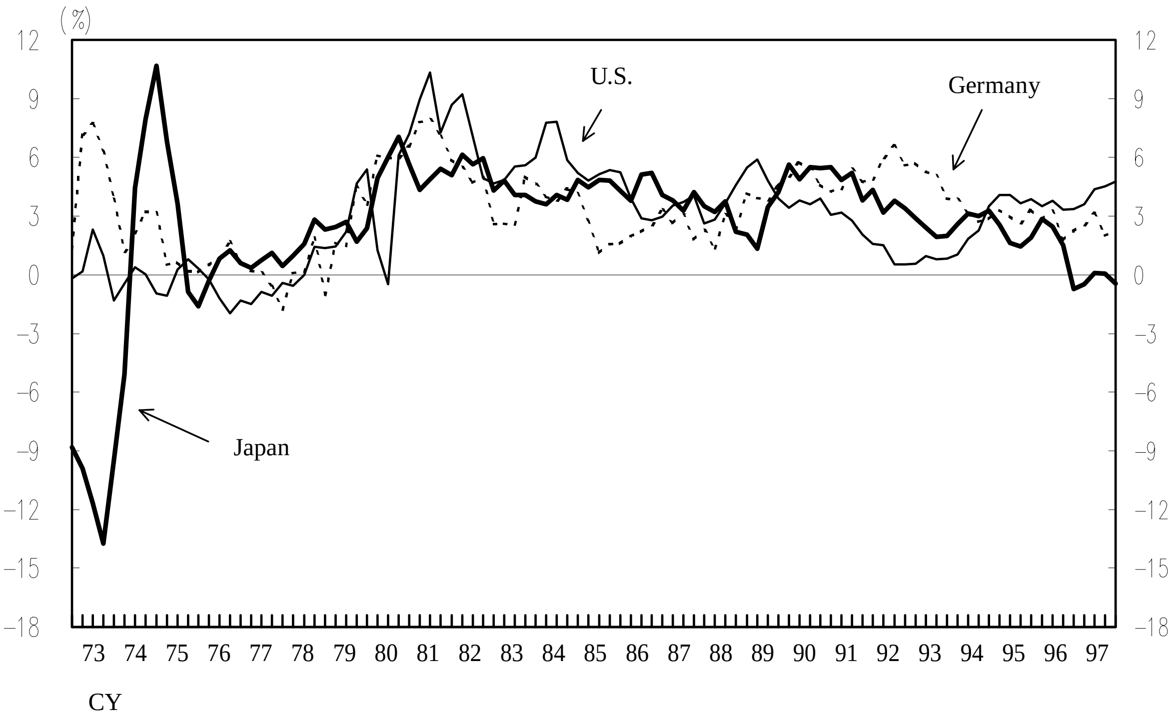
6 For example, Mishkin (1984) showed empirically that domestic real interest rates in different countries have not yet been equalised. Barro and Sala-i-Martin (1990) also described empirical results showing that domestic real interest rates are significantly affected not only by world factors such as world saving rates or world investment rates, but also by domestic factors. From these analyses, it can be inferred that real interest rates in different countries are still affected by domestic factors even amid the globalisation of financial markets.

7 An explanation of the risk premium stemming from the imperfect substitution between domestic and foreign assets comes from Kawai (1994). Shiratsuka and Nakamura (1998) point to five factors which prevent international investment diversification: (1) exchange rate volatility risk, (2) institutional and social factors in each country, (3) asymmetric information, (4) various kinds of regulations imposed on financial transactions, and (5) sovereign risk.

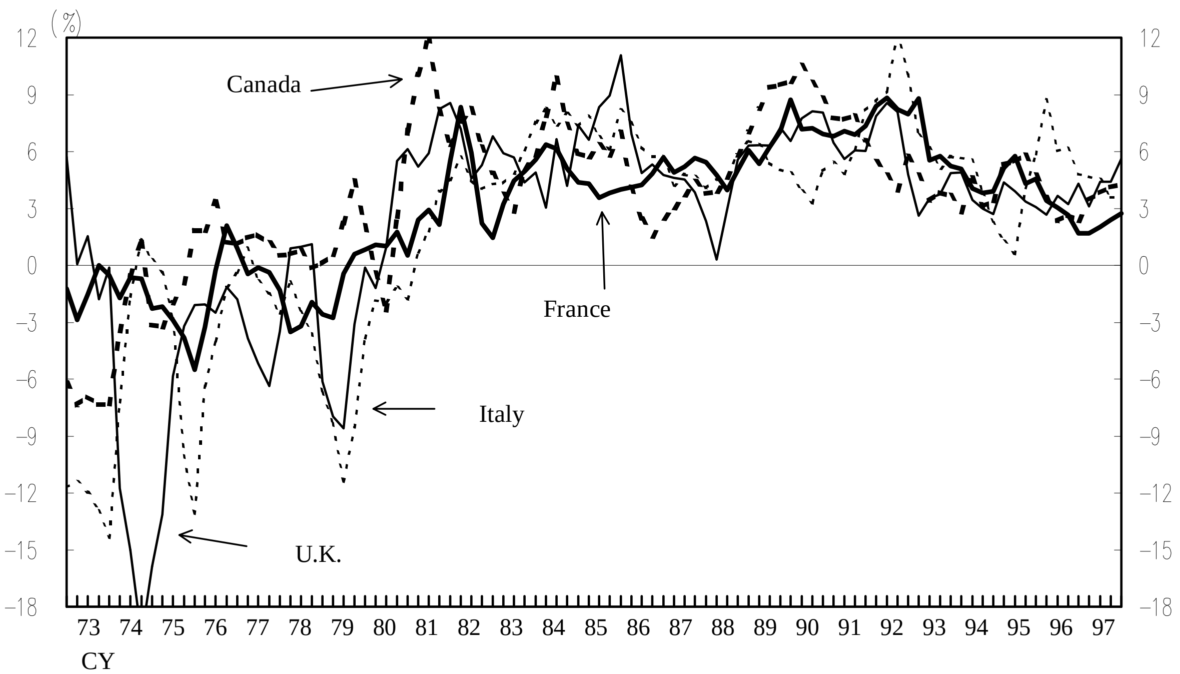
Chart 2

Real Short-Term Interest Rates of MI-7 Countries

(1) U.S., Japan, Germany



(2) U.K., France, Italy, Canada



2.2 The panel analysis

2.2.1 The model of empirical analysis

In this section, we study the determnation of real interest rates in G7 countries by empirical analysis using panel data, in order to focus on the relationship between globalising financial markets and the effectiveness of monetary policy.[8]

From the previous section, we can see that domestic monetary policy does, to some degree, affect the real long-term interest rate through its effects on the real short-term interest rate and arbitrage transactions between short- and long-term interest rates. However, if real interest rates in different countries were equalised, there would be less room for monetary policy in each country to affect globally equalised real interest rates. Thus, in the empirical analysis, as an explanatory variable we took the real short-term interest rate as a proxy for domestic monetary policy in order to determine whether monetary policy has significant effects on the domestic real long-term interest rate amid the globalisation of financial markets.

In addition, we used the accumulated ratio of domestic current accounts to nominal GDP (hereafter referred to as CA/GDP) as an explanatory variable in order to determine whether the risk premium stemming from the imperfect substitution of domestic and foreign assets is reflected in the domestic real long-term interest rate. An increase in CA/GDP simultaneously means an increase in both foreign assets held by domestic investors and the risk attaching to holding them. Thus, the increase in CA/GDP lowers the domestic real long-term interest rate and raises foreign real interest rates by an amount corresponding to that risk premium (Chart 3).[9]

The model specification[10] is as follows:

(1) $$r^L_{i,t} = \alpha_0 + \beta_i + \gamma_t + \alpha_1 r^S_{i,t} + \alpha_2 CAG_{i,t} + \varepsilon_{i,t}$$

where $r^L_{i,t}$ is the real long-term interest rate of G7 country i in period t, $r^S_{i,t}$ is the real short-term interest rate,[11] $CAG_{i,t}$ is CA/GDP and $\varepsilon_{i,t}$ is the error term. Two sets of dummy variables are

---

8 The framework of the empirical analysis in this section is based on Ishi (1996).

9 Note that CA/GDP, which is only a proxy variable for the imperfect substitution between domestic and foreign assets, does not necessarily reflect all factors causing this imperfect substitution as described earlier.

10 As described previously, the difference between domestic and foreign real interest rates depends both on the risk premium stemming from imperfect substitution between domestic and foreign assets and on expected changes in the real exchange rate. To estimate the effects of expected changes in the real exchange rate on the real long-term interest rate, we added deviations of actual real effective exchange rates of G7 countries from their trends to the explanatory variable of the regression model, as suggested by Ishi (1996), and re-estimated it. The proxy for expected changes in the real exchange rate has significant effects on the real long-term interest rate. That is, if the actual real exchange rate is higher than its trend for one period, market participants are assumed to expect the real exchange rate to depreciate and the real long-term interest rate in the investors' country is higher than those of other countries. On the other hand, two other variables of this model, the real short-term interest rate and CA/GDP, have almost the same effect on the real long-term interest rate even when the model is estimated without the variable of expected change in the real exchange rate. This suggests that not only the risk premium stemming from the imperfect substitution between domestic and foreign assets but also the expected change in the real exchange rate possibly influence the spread between domestic and foreign real interest rates. However, the proxy variable in the above model may not be reliable in representing expectations of future exchange rate changes because its movement depends the detrended model used. We therefore disregard the expected real exchange rate in the analysis below.

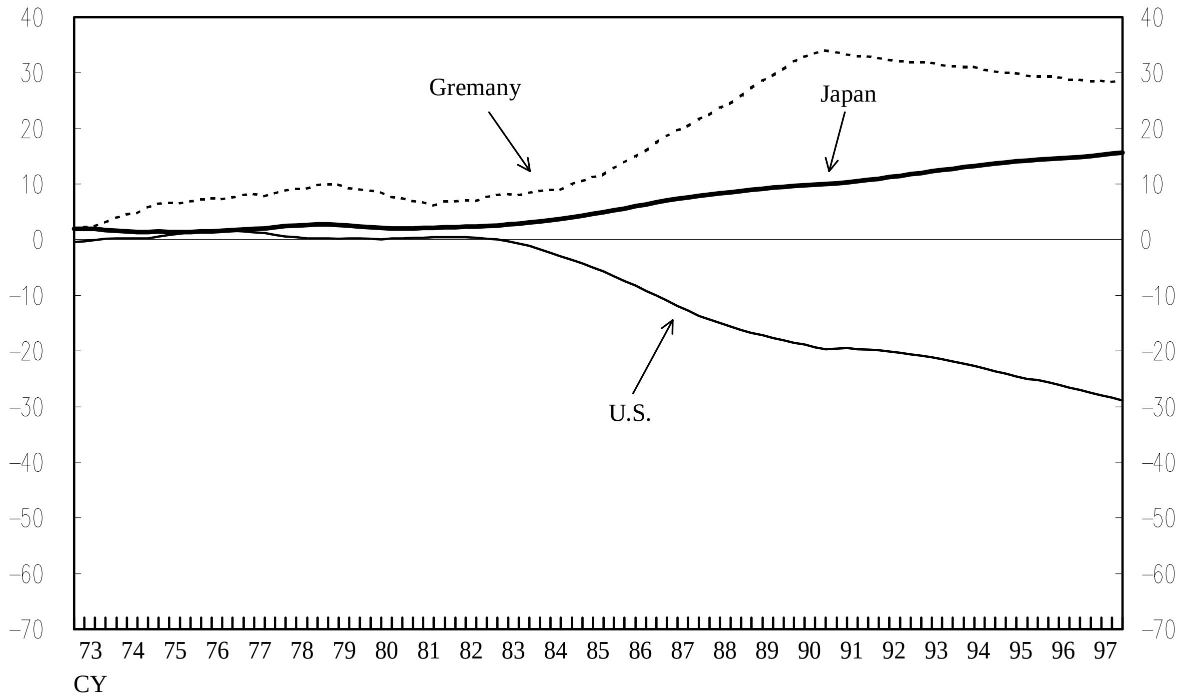
11 In general, it is difficult to calculate the real interest rate of different countries. In this section, we determine the real short-term interest rate by subtracting GDP deflator changes from one quarter earlier to two quarters later from the nominal short-term interest rate. This is equivalent to assuming that investors forecast inflation two quarters ahead based on actual inflation information. On the other hand, the real long-term interest rate is calculated by subtracting GDP deflator changes one year ahead from the nominal long-term interest rate. This is equivalent to assuming that investors forecast inflation one year ahead, with more forward-looking behaviour in the long run than in the short run.

included in the model: the country dummies, β_i, which capture domestic factors and time dummies, γ_t, which capture common shocks to all countries in one period, such as global financial

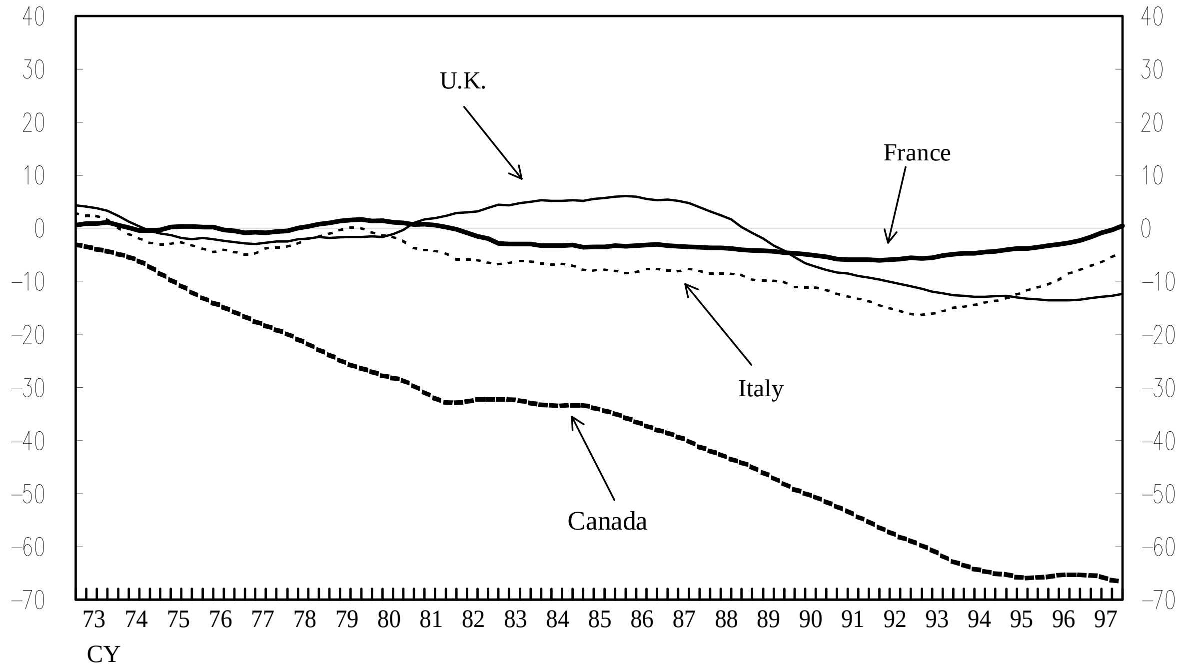
Chart 3

CA/GDP of MI-7 Countries

(1) U.S., Japan, Germany



(2) U.K., France, Italy, Canada



shocks.[12] The parameter for CA/GDP, α_2, is expected to be negative theoretically. In this empirical analysis, we estimate the above regression model for three periods using quarterly data.[13] The first period, 1973Q1–1980Q4, is characterised by acceleration of inflation, the second period, 1981Q1–1986Q4, by deceleration of inflation, and the third period, 1987Q1–1997Q4, by price stability. We also estimate the model using the rolling regression method with 10-year window to investigate how the estimated parameters change in different sample periods.

2.2.2 Estimation results and implications

The results of the empirical analyses are shown in Table 2 and Chart 4-3. In the following, we discuss the main results and the implications.

(1) The real short-term interest rate, a proxy variable for monetary policy, significantly affects the real long-term interest rate in all sample periods, which implies that domestic monetary policy also has a significant effect on it even amid the globalisation of financial markets.

Table 2

Estimation results of panel analysis
(results for three sample periods)

Sample period from 1973Q1 to 1980Q4					
	Dependent variable: real long-term interest rate				
Explanatory variable	OLS	One-way fixed effect	One-way random effect	Two-way fixed effect	Two-way random effect
Constant term	0.193		0.092	–0.085	0.029
	(0.95)		(0.30)	(0.52)	(0.08)
Real short-term interest rate	0.748**	0.622**	0.691**	0.515**	0.617**
	(17.84)	(13.02)	(15.90)	(12.62)	(16.73)
CA/GDP	0.029	–0.105*	–0.002	0.016	0.016
	(1.11)	(1.91)	(0.04)	(0.35)	(0.51)
Lagrange multiplier test: One-and two-way random effect vs OLS			13.86 (0.00)		61.42 (0.00)
Hausman test: One-way fixed vs one-way random effect			12.31 (0.00)		38.19 (0.00)
Adjusted R-squared	0.588	0.633		0.773	
	Hypothesis test (p-values are in parentheses)				
	Likelihood ratio test: x^2			F-test	
One-way fixed effect vs OLS	32.52 (0.00)			5.51 (0.00)	
Two-way fixed effect vs OLS	176.35 (0.00)			5.80 (0.00)	
Two-way fixed effect vs one-way fixed effect	144.30 (0.00)			5.37 (0.00)	

[12] The country and time dummies are included in all sample periods because statistical tests reject the null hypothesis that they are equal to zero.

[13] The historical movements of three variables in the model, the domestic real long-term interest rate, the real short-term interest rate and CA/GDP of the relevant G7 country, are shown in Charts 1 to 3.

Table 2 (cont.)

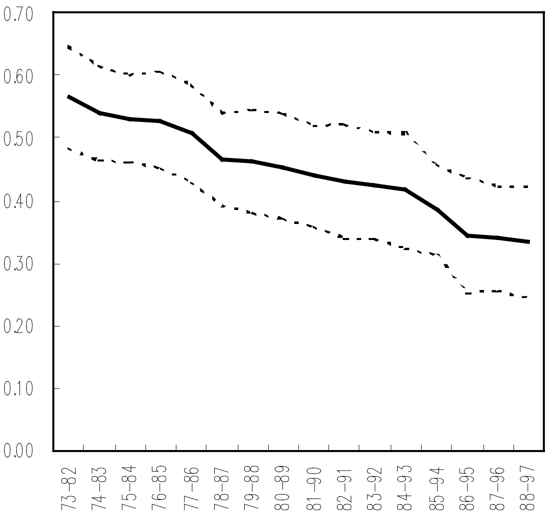
Sample period from 1981Q1 to 1986Q4					
Constant term	3.975*		4.024**	4.615**	4.390**
	(12.91)		(9.16)	(15.42)	(9.89)
Real short-term interest rate	0.415**	0.409**	0.410**	0.317**	0.342**
	(7.55)	(7.60)	(7.68)	(6.63)	(7.39)
CA/GDP	–0.035**	–0.003	–0.029	–0.005	–0.028
	(3.99)	(0.07)	(1.30)	(0.13)	(1.34)
Lagrange multiplier test: One- and two-way random effect vs OLS			55.24 (0.00)		85.44 (0.00)
Hausman test: One-way fixed vs one-way random effect			0.39 (0.82)		5.02 (0.08)
Adjusted R-squared	0.349	0.464		0.660	
			Hypothesis test (p-values are in parentheses)		
	Likelihood ratio test: x^2			F-test	
One-way fixed effect vs OLS	38.77 (0.00)			6.88 (0.00)	
Two-way fixed effect vs OLS	142.65 (0.00)			6.06 (0.00)	
Two-way fixed effect vs one-way fixed effect	103.88 (0.00)			5.06 (0.00)	
Sample period from 1987Q1 to 1997Q4					
Constant term	3.470**		3.499**	3.161**	3.447**
	(20.48)		(13.12)	(14.69)	(12.73)
Real short-term interest rate	0.340**	0.303**	0.296**	0.346**	0.314**
	(9.57)	(8.49)	(8.41)	(8.30)	(8.93)
CA/GDP	–0.024**	–0.093**	–0.043**	–0.057**	–0.040**
	(8.00)	(7.24)	(6.11)	(4.44)	(5.78)
Lagrange multiplier test: One- and two-way random effect vs OLS			94.14 (0.00)		127.11 (0.00)
Hausman test: One-way fixed vs one-way random effect			22.76 (0.00)		4.89 (0.09)
Adjusted R-squared	0.386	0.511		0.602	
			Hypothesis test (p-values are in parentheses)		
	Likelihood ratio test: x^2			F-test	
One-way fixed effect vs OLS	76.411 (0.00)			14.03 (0.00)	
Two-way fixed effect vs OLS	188.99 (0.00)			4.34 (0.00)	
Two-way fixed effect vs one-way fixed effect	112.58 (0.00)			2.63 (0.00)	

Notes: Figures in parentheses below the estimated parameters indicate t-values. ** and * indicate significance of the estimated parameters at the 1% and 5% levels respectively. In the process of model selection, the smaller the p-value of likelihood ratio- and F-tests, the more the one-way fixed effect model is likely to be preferred to either OLS or the one-way fixed effect model. In addition, the smaller the p-value of the Lagrange multiplier test, the more the one-way and two-way random effect models are likely to be chosen than OLS. And the smaller the p-value of the Hausman test, the more the one-way and two-way fixed models are likely to be chosen than one-way and two-way random effect models. The selected models are shaded.

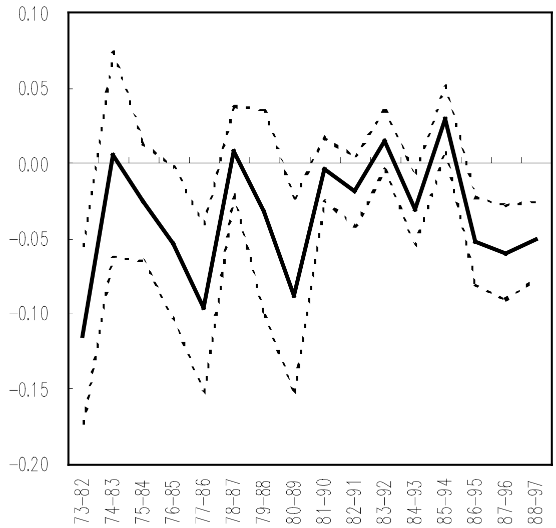
Chart 4-3

(2) Results of Rolling Regression

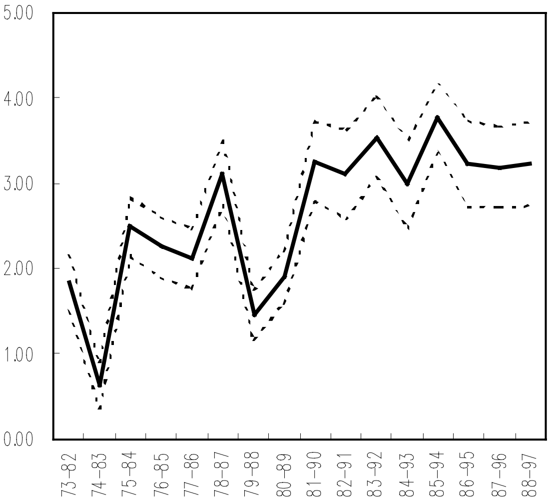
(A) Real short-term Interest Rate



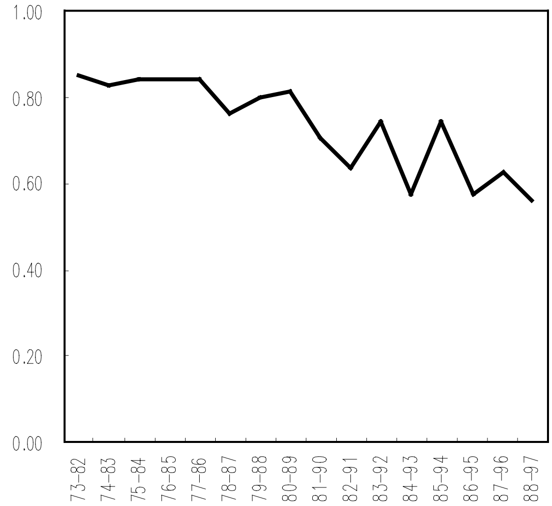
(B) CA/GDP



(C) Constant Term



(D) Adjusted R-Squared



Note:
(1) Two way fixed effect models are chosen in all sample periods. The model contains both country and time dummies in explanatory variables. Here we omit their estimation results.
(2) In the above charts, the bold lines indicate the estimated parameters of explanatory variables in the model, and dotted lines estimated parameters ± 2 × their standard deviations, which indicates a 5 percent significance level.

However, the later the sample period, the smaller the estimated parameter of the real short-term interest rate, α_1. Thus, the influence of monetary policy on the real long-term interest rate has been decreasing year by year.

(2) From the late 1980s, the parameter for CA/GDP, α_2, has had a significant effect on the real long-term interest rate. This implies that the risk premium stemming from imperfect substitution between domestic and foreign assets has pushed down the real long-term interest rate of the

country which holds net foreign assets, and pushed up that of the country which holds net foreign liabilities.[14]

In other words, this risk premium implies that the more foreign assets domestic investors have, the higher the returns they require for compensation for risks involved in holding such assets.

Note that the parameter for CA/GDP is significant only in the sample periods after the late 1980s. This is because the current account imbalances in G7 countries were so small in the 1970s and early 1980s that the effect of CA/GDP could not be extracted by empirical analysis, although the mechanism of home bias had possibly worked even in those periods. On the other hand, as current account imbalances increased after the late 1980s, the phenomenon of home bias has become statistically significant.

(3) There seems to be little difference between the determinants of real long-term interest rates in Japan and the other G7 countries. This can be confirmed by decomposing the sum of squared residuals of the model into the part contributed by each country. Although the weight contributed by Japan is higher than those of other countries except for the United Kingdom in sample period 1, it is almost the same as them or rather lower in sample periods 2 and 3, as shown in Table 3. These facts suggest that the determinants of Japan's real long-term interest rate are not necessarily much different from those in other G7 countries.

The fact that Japan's real long-term interest rate is relatively lower than those of G7 countries in the later periods is consistently explained by the following two factors: the low real short-term interest rate, brought about by the Bank of Japan's extremely easy monetary policy, and the large positive CA/GDP, which has held down Japan's real long-term interest rate until now.

Table 3
Analysis of sum of squared residuals of the model

Sample period	US	JP	DE	UK	FR	IT	CA	Sum of the squared residuals	R-squared
(1) Contribution of each country									
1973Q1–1980Q4	0.84	4.46	1.83	7.04	0.81	2.33	1.28	18.59	81.41
1981Q1–1986Q4	2.39	4.05	2.43	5.29	3.77	3.02	6.55	27.50	72.50
1987Q1–1997Q4	2.49	2.69	3.11	5.46	4.03	12.10	3.14	33.02	66.98
Sample period	US	JP	DE	UK	FR	IT	CA	SUM	
(2) Country weight									
1973Q1–1980Q4	4.54	23.98	9.86	37.85	4.37	12.53	6.87	100.00	
1981Q1–1986Q4	8.68	14.73	8.82	19.24	13.72	10.98	23.82	100.00	
1987Q1–1997Q4	7.53	8.16	9.42	16.53	12.22	36.64	9.51	100.00	

Note: The contributions of each country to the sum of squared residuals of the model in (1) are multiplied by 100.

[14] The risk premium imposed on holding foreign assets may include some sovereign risk of the country issuing these foreign bonds. In this analysis, we tried to use the ratio of financial liability of general government to nominal GDP, as a proxy for sovereign risk, as the explanatory variable. However, we did not find evidence that the variable has a significant effect on the real long-term interest rate.

3. Effects of the global financial crisis on Japanese financial markets in autumn 1998

Generally speaking, domestic short-term interest rates are likely to be under the control of the central bank even given the globalisation of financial markets. However, can we say that the domestic short-term financial market is well controlled by the central bank in the event of global financial stress?

In autumn 1998, we observe that either a deterioration in the creditworthiness of Japanese financial institutions in the eyes of market participants or a credit contraction with a drying-up of dollar liquidity led to an increase in the Japan premium imposed on dollar fundings amid the global financial crisis. As a result, Japanese short-term interest rates were exposed to upward pressure.

Below, we review the behaviour of Japanese financial institutions and arbitrage relationships among some financial markets in autumn 1998 (Section 3.1), and consider the Bank of Japan's control over the domestic short-term financial market (Section 3.2).

3.1 The Japan premium, market interest rates and the behaviour of financial institutions

The Japan premium[15] (Chart 5), which reflects the differences in dollar funding costs of Japanese and foreign financial institutions, increased by 1 percentage point in autumn 1997, when the Hokkaido Takushoku Bank and Yamaichi Securities went bankrupt. Afterwards, although it decreased to 0.2 points temporarily in May 1998, it began to quickly increase again and reached 0.91 points at the beginning of November.[16]

According to market participants, the reason for the increase in the Japan premium in 1998 was the same as in 1997 in that the creditworthiness of Japanese financial institutions had deteriorated, that is, solvency risk had heightened.[17] However, the surge in autumn 1998 was probably affected by greater dollar liquidity risk,[18] which led to Japanese financial institutions finding it difficult to raise dollar funds. Reasons were both a credit contraction and a drying-up of dollar liquidity in global financial markets that were caused by the Russian debt crisis – the depreciation of the Russian rouble and subsequent debt moratorium – and the near-collapse of LTCM.

Faced with such a difficult financial situation, Japanese financial institutions tried to procure yen funds in domestic and global financial markets and to convert them into dollar funds through yen/dollar swap transactions.[19] Consequently, this added to the demand for yen funds, which were necessary for yen/dollar swap transactions. This, together with a rise in the risk premium attaching to yen fundings of Japanese financial institutions, increased upward pressure on yen interest rates. The risk premium for raising yen funds, as given by the difference between the euroyen TIBOR and the risk-free yen treasury bill rate, widened from October to the beginning of November, as shown in Chart 6.

---

15 In this section, we define the Japan premium as three-month dollar TIBOR minus three-month dollar LIBOR.

16 When Cosmo Credit Cooperative, Kizu Credit Cooperative and Hyogo Bank went bankrupt and the illegal transactions in the New York branch of Daiwa Bank were exposed in 1995, the creditworthiness of Japanese financial institutions deteriorated and the Japan premium increased. For details of the Japan premium in autumn 1997, see Bank of Japan (1998).

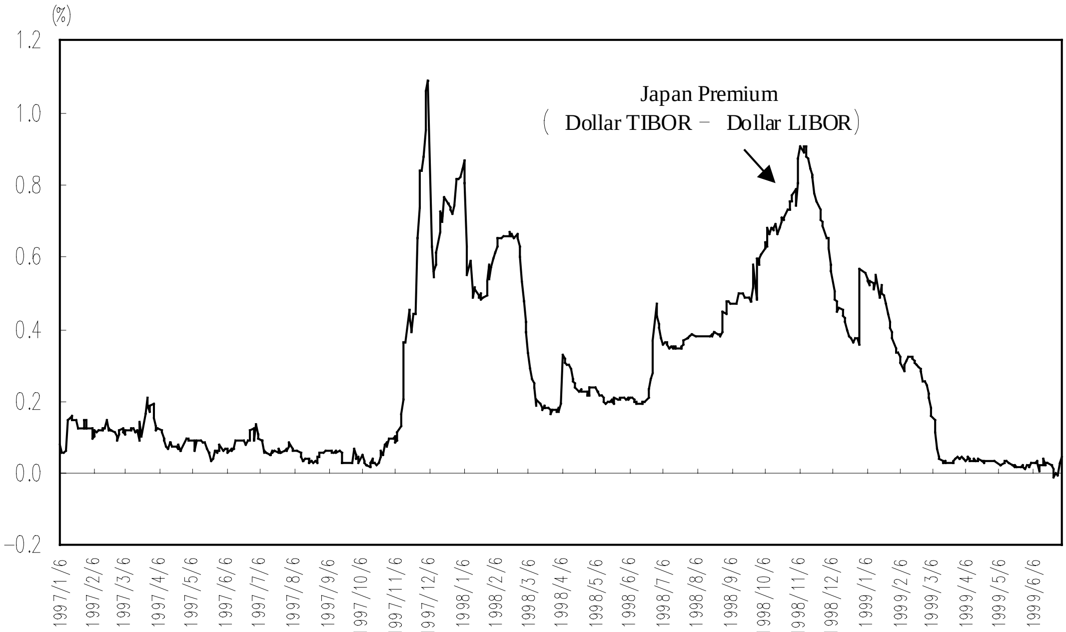
17 In 1998, the failure of LTCB, whose bankruptcy was rumoured in June and which was temporarily nationalised in October, and uncertainty over the passing of laws for the revitalisation of the financial system increased concerns about the soundness of Japanese financial institutions and the entire Japanese financial system.

18 Conceptually, the Japan premium is equal to the premium on the default risk of Japanese financial institutions compared with that of foreign financial institutions. The default risk is the sum of solvency risk and liquidity risk. However, it is quite difficult to directly observe solvency and liquidity risk.

19 In this case, transactions in which Japanese financial institutions receive dollars and foreign financial institutions yen at the start date, and Japanese financial institutions receive yen and foreign financial institutions dollars at the predetermined forward exchange rate on the end date of the transactions.

Chart 5

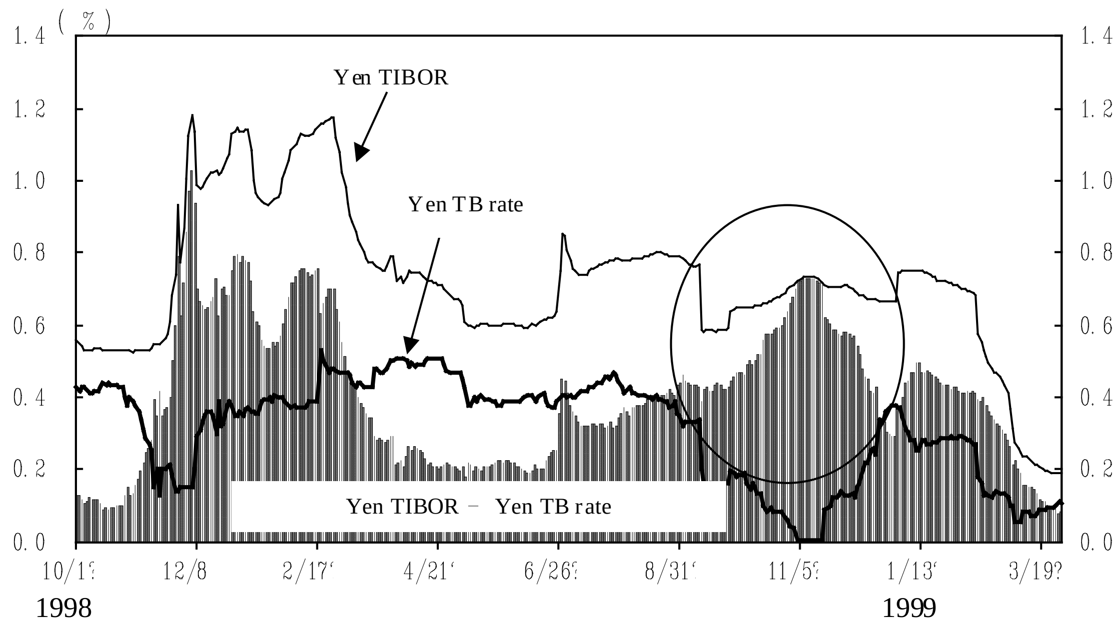
Japan Premium



Note:
3-month Dollar TIBOR and 3-month Dollar LIBOR.

Chart 6

Short-term Interest Rates

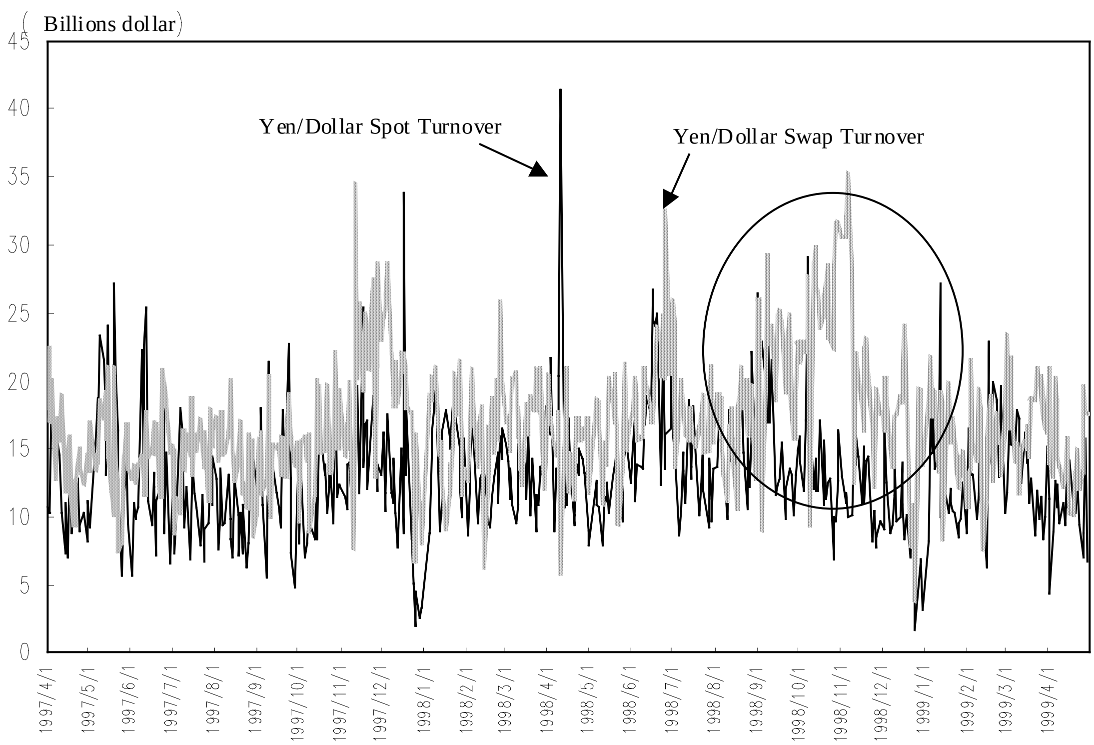


Note:
3-month Yen TIBOR and 3-month Dollar LIBOR.

The reason Japanese financial institutions engaged in a lot of yen/dollar swap transactions at that time is that such transactions were easier than uncollateralised direct dollar fundings. This implies that whereas the supply side of dollar funds bears the counterparty's default risk in uncollateralised transactions, in yen/dollar swap transactions, in which foreign financial institutions receive yen as collateral, there is relatively less risk. Therefore, yen/dollar swap transactions provided a good opportunity to raise dollar funds for Japanese financial institutions with relatively low credit ratings, which could hardly raise dollar funds without collateral.[20]

Chart 7

Yen/Dollar Spot and Yen/Dollar Swap Turnover



If Japanese financial institutions could have raised dollar funds smoothly through yen/dollar swap transactions, the liquidity risk portion of the Japan premium would have been eliminated, although the solvency risk portion would have partially remained. However, when the global financial crisis occurred in autumn 1998, the suppliers of dollar funds, especially foreign financial institutions, tended to restrict yen/dollar swap transactions with Japanese financial institutions.[21] Hence, the difficulty faced by Japanese financial institutions in procuring foreign currency was not eased immediately.

---

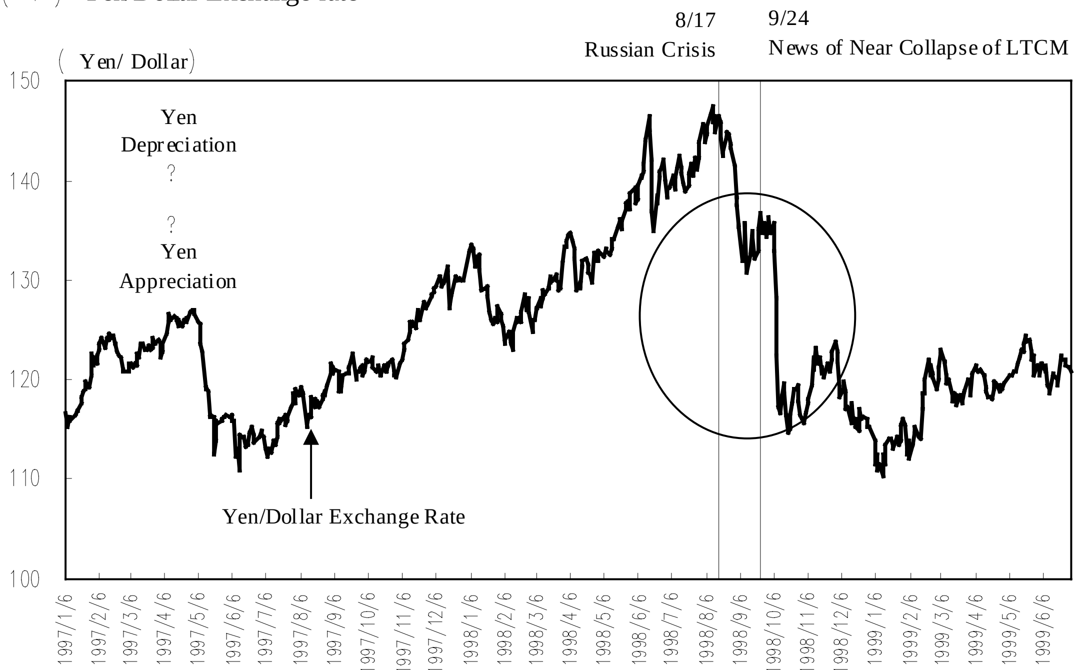
[20] Chart 7 shows that yen/dollar swap turnover was more than yen/dollar spot turnover in autumn 1997 and autumn 1998, as Hanajiri (1999) pointed out in his paper.

[21] Some possible factors explaining the behaviour of foreign financial institutions are as follows: first, profits of many foreign financial institutions had deteriorated and their risk-taking capacity had weakened due to global financial shocks in autumn 1998. In addition, they experienced large volatility in the yen/dollar spot exchange rate, as shown in Chart 8, and had few opportunities to invest yen funds (obtained through yen/dollar exchange swap transactions with Japanese financial institutions) in risk-free assets (since there were insufficient risk-free assets, i.e. yen treasury and financing bills) in Japan's short-term financial market (Hanajiri (1999)).

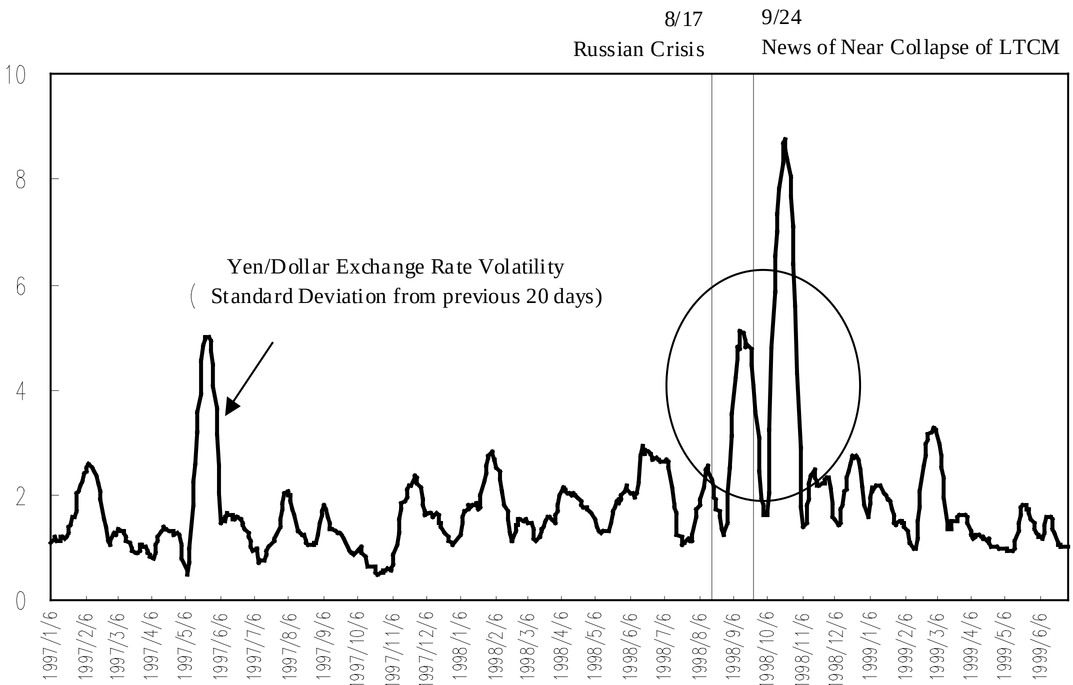
Chart 8

Yen/Dollar Exchange Rate and Volatility

（１）Yen/Dollar Exchange rate

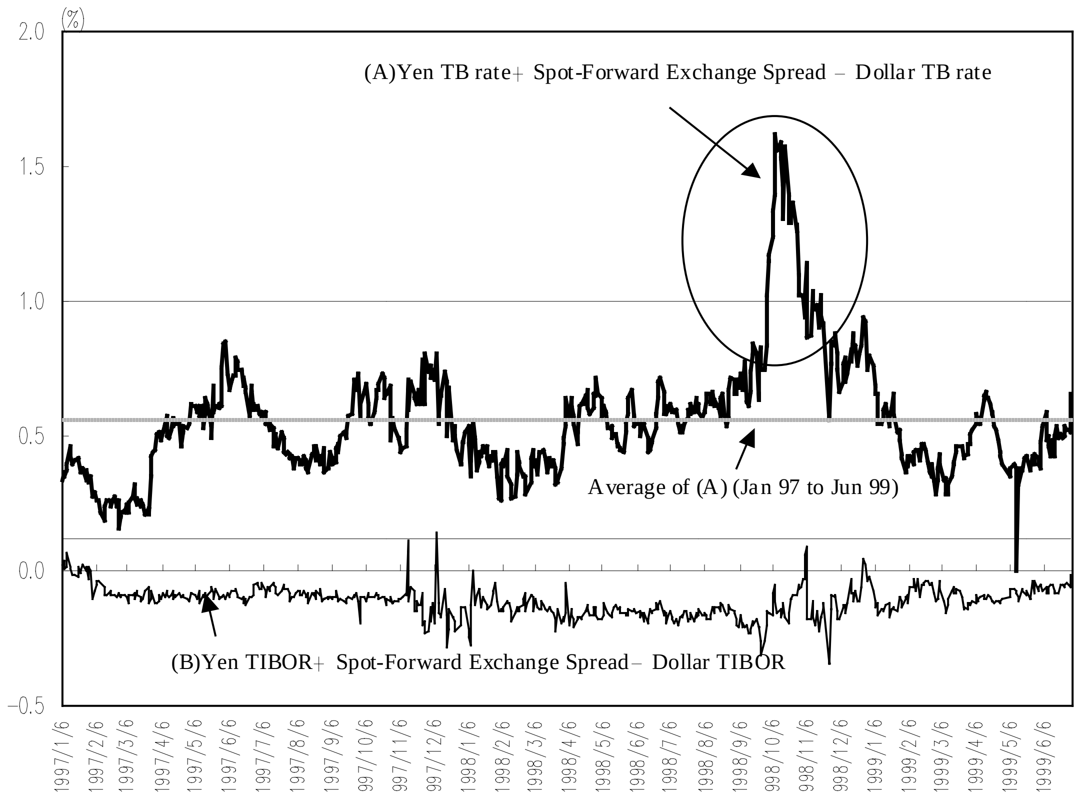


（２）Yen/Dollar Exchange Rate Volatility



With the quantitative restriction, prices do not work efficiently to clear the markets. In autumn 1998, as foreign financial institutions restricted yen/dollar swap transactions, a distortion of arbitrage transactions between domestic and foreign interest rates was observed in short-term financial markets. As shown in Chart 9, the arbitrage relation between yen and the dollar risk-free rates, that is, yen and

Arbitrage Relation between Yen/Dollar Markets



Notes:

(1) The lines above and below the average (A) "Yen TB rate+ Spot-Forward Exchange Spread− Dollar TB rate" are the average ±2 × standard deviation.

(2) The Yen TB rate, Dollar TB rate, Yen TIBOR, and Dollar TIBOR are 3-month terms.

dollar treasury bill rates, adjusted by the spot and forward exchange rate spread, was not maintained, a phenomenon which was not observed in autumn 1997.[22]

In the same way, the spread between the cost for foreign financial institutions of converting from dollar to yen funds and the yen treasury bill rate, whose mean value is around 0.15% on average, decreased remarkably or went below zero from the end of September to December 1998.[23] This suggests the strong risk-averting stance of foreign financial institutions and the existence of quantitative restrictions on yen/dollar swap transactions.[24]

---

22 According to Chart 9, on the other hand, the arbitrage relation between yen and dollar TIBOR adjusted by the yen/dollar spot and forward exchange spread was maintained in this period.

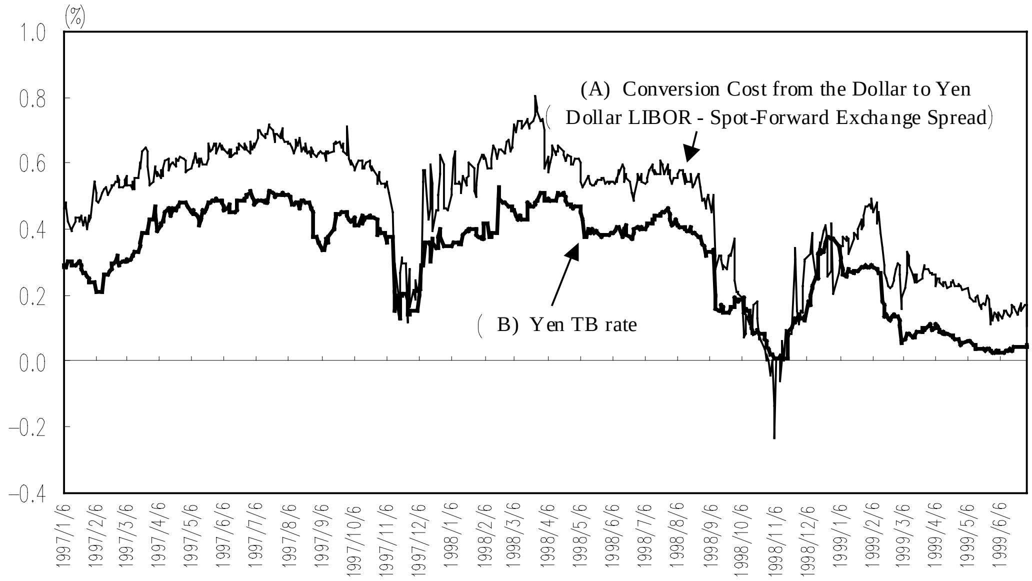
23 In autumn 1997, we can also observe an increase in the gap between the cost for foreign financial institutions of converting from yen to dollar funds and the yen treasury bill rate. However, the narrowing of this gap in autumn 1998 was more pronounced and longer than in autumn 1997.

24 Reasons for the arbitrage distortion in Charts 9 and 10 are that the yen treasury bill rate was too low to decline in the face of a zero bound and that a deterioration in the creditworthiness of Japanese financial institutions was reflected in the yen treasury bill rate. However, periods in which the yen treasury bill rate was zero were few during the arbitrage distortion period. In addition, although one private rating company, Moody's Investors Service, lowered its rating on yen bonds

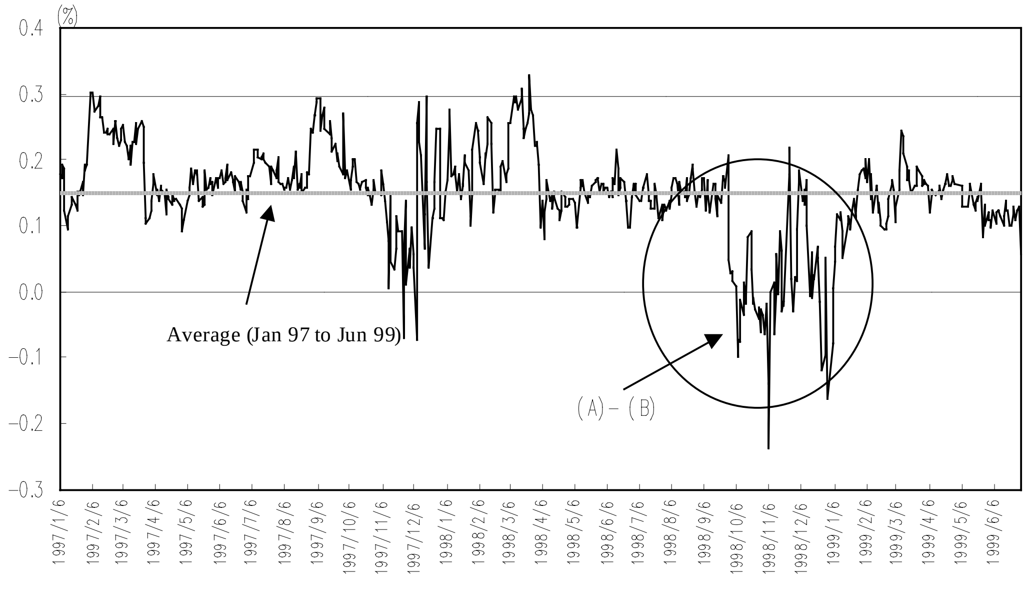
Chart 10

Conversion Costs of Foreign Financial Institutions from the Dollar to Yen and the Yen TB Rate

（１）Conversion Cost of Foreign Financial Institutions from the Dollar to Yen, and the Yen TB Rate.



（２）（Ａ）－（Ｂ）

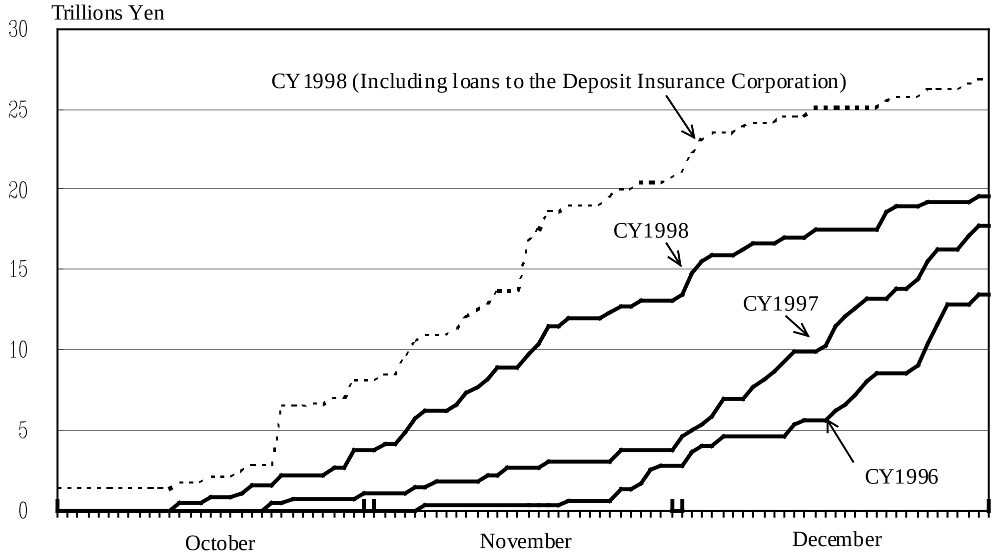


Notes:
(1) The lines above and below the average (A) "Conversion Cost of foreign financial institutions from the Dollar to Yen" minus (B) "Yen TB rate" in the lower panel are average series ± 2 × standard deviation.
(2) 3-month Yen TB rate and 3-month Dollar LIBOR.

---

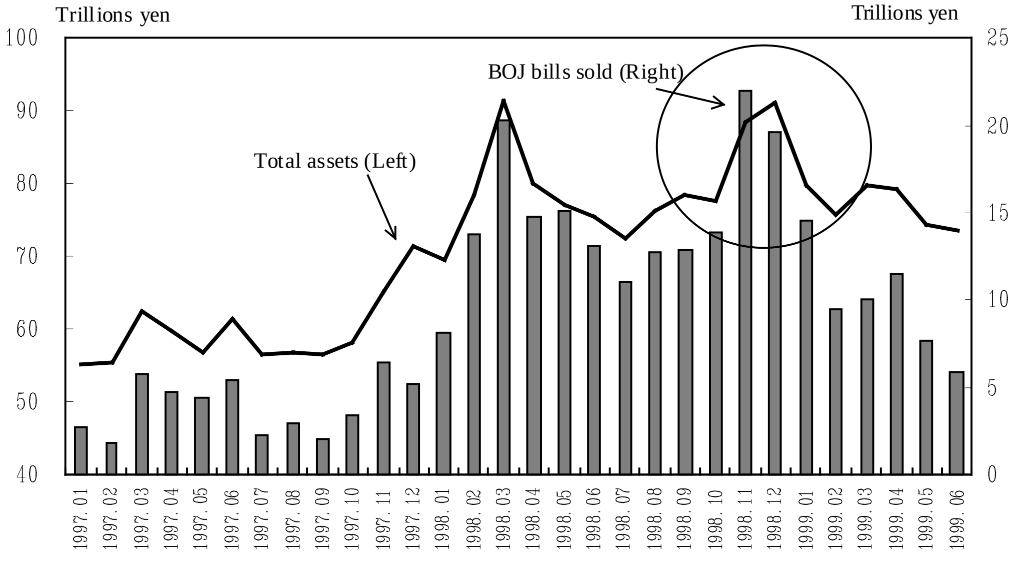
issued and secured by the Japanese government from Aaa to Aa1 on 17 November 1998, distortion of the arbitrage relation had already been observed. Hence, we believe that this analysis are not affected by such factors.

Injection of Yen Funds beyond the End of the Calendar Year



Note:
The injection of yen includes loans except for the special loans provided under Article 38 of the Bank of Japan Law of 1997 (Article 25 of the former Bank of Japan Law), outright purchases of bills and some money market operations, such as purchases of TBs/FBs under repurchase agreement, JGB repo operations, purchases of JGB under repurchase agreements and purchases of CPs under repurchase agreement.

BOJ Bills Sold and Total Assets of the Bank of Japan



Note:
BOJ bills sold and total assets of the Bank of Japan as of the end of each month.

3.2 Monetary policy operations of the Bank of Japan and their effects

In response to this tough financial situation, the Bank of Japan conducted money market operations by injecting ample yen funds using instruments with relatively long maturities (beyond the end of the calendar year) in order to mitigate the upward pressure on short-term yen interest rates. Simultaneously, the Bank absorbed excess yen funds by selling bills with short maturities in an attempt to prevent the overnight call rate, Japan's interbank rate, from decreasing excessively (Chart 11; Bank of Japan (1999)). These money market operations had the following effects.

First, the injection of ample yen funds for conversion into dollar funds had a direct effect in mitigating upward pressure on the short-term yen interest rates caused by the procurement of yen funds.

Second, the injection of ample yen funds implies that the Bank of Japan supplied these funds for Japanese financial institutions to convert into dollars. In this way, the Bank of Japan supported Japanese financial institutions' dollar financing. At this time, in fact, because foreign financial institutions restricted quantities in yen/dollar swap transactions, the difficulty of Japanese financial institutions in raising dollars was not completely eased. However, if it had not been for the Bank of Japan's money market operations, the Japanese financial situation might have been more confused.

Third, market participants complained that Japanese markets for risk-free yen assets, such as treasury bills and financing bills, were so small that foreign financial institutions were forced to restrict yen/dollar swap transactions (see footnote 21). In reality, excessive demand for treasury bills is evidenced by the fact that the treasury bill rate fell to zero at the beginning of November 1998. In this respect, the operations of the Bank of Japan to absorb excess yen by BOJ bill sales contributed to providing risk-free yen assets to the market, and consequently led to the activation of yen/dollar swap transactions. In fact, most of the buyers of these bills were foreign financial institutions (Shirakawa (1999)).

Lastly, the easing of dollar procurement by Japanese financial institutions, described above, seemed to reduce the default risk of Japanese financial institutions and the Japan premium. These effects also worked to reduce the short-term yen interest rate by decreasing the risk premium on yen funds.

From the above discussions, the money market operations of the Bank of Japan in autumn 1998, that is, the aggressive injection of yen and BOJ bill sales, had some effect in mitigating upward pressure on yen interest rates induced by both the drying-up of dollar liquidity and the malfunction of swap transactions. Nonetheless, it could not mitigate the increase in the Japan premium stemming from solvency risk.

In addition, global financial markets regaining stability after the interest rate reductions by the Federal Reserve and increased confidence in Japan's financial system following the enactment of financial legislation enabled the short-term yen interest rate to decrease after mid-November.

4. Concluding remarks

In this paper, we analysed both the determinants of real interest rates in G7 countries and the impact of the global market crisis in autumn 1998 on Japan's short-term financial market, in order to examine the effectiveness of monetary policy amid the globalisation of financial markets.

From the empirical analysis of the determinants of real interest rates in G7 countries in Section 2, we found that monetary policy has a significant effect on domestic real long-term interest rates, and that the risk premium stemming from the imperfect substitution between domestic and foreign assets also had a significant impact from the late 1980s. The latter indicates a home bias whereby domestic investors require higher returns for holding foreign assets. In addition, the determinants of Japan's real long-term interest rate are not much different from those in other countries. All this implies that the real interest rates of different countries have not yet been equalised, and that monetary policy still has a significant effect on the domestic economy through its influence on the real long-term interest rates despite the globalisation of financial markets.

However, it should be noted that the estimation results show that the direct effects of monetary policy on real long-term interest rates have been gradually weakening over time. In this respect, it is worthwhile to explore the effects of monetary policy on real long-term interest rates further, including indirect effects through the risk premium.[25]

In Section 3, we considered the effects of the global financial crisis in autumn 1998 on Japan's short-term financial market. The increase in the Japan premium and upward pressure on short-term yen interest rates were aggravated by the contraction in dollar lending and swap transactions by foreign financial institutions, not to mention the erosion of Japanese financial institutions' creditworthiness. These phenomena of credit contraction and the drying-up of dollar liquidity were observed in the distortion of the arbitrage relation between Japanese and US short-term financial markets.

To tackle this situation, the Bank of Japan injected ample yen funds using instruments with relatively long maturities (beyond the end of the calendar year) on one hand, and absorbed excess yen funds through BOJ bill sales to prevent the overnight call rate from excessively decreasing on the other. These money market operations are likely to have contributed to mitigating upward pressures on the short-term interest rate through the direct effect of the supply of yen funds and the indirect effect of prompting Japanese financial institutions to convert yen into dollars, which consequently reduced the Japan premium and risk premium on yen funds.

[25] According to the results of rolling regression, the adjusted-R squared falls from about 0.8 to 0.6 as in later sample periods. This suggests that the explanatory power of the real short-term interest rate and CA/GDP with respect to the real long-term interest rate has been weakening. In this paper, we did not investigate further, however, it is important to consider those factors amid the globalisation of financial markets.

Appendix

Determinants of the real interest rates in MI-7 countries

Data	Content	Source
Real long-term interest rate	The real long-term interest rate is the nominal long-term interest rate minus inflation one year ahead. $r_{i,t}^{L} = i_{i,t}^{L} - [(P_{i,t+4}/P_{i,t}) - 1)]$ where $r_{i,t}^{L}$ is the real long-term interest rate of country i in period t, $i_{i,t}^{L}$ the nominal long-term interest rate and $P_{i,t}$ the GDP deflator.	OECD, "National Accounts", etc.
Real short-term interest rate	The real short-term interest rate is the nominal short-term interest rate minus actual inflation from one quarter back to two quarters ahead. $r_{i,t}^{S} = i_{i,t}^{S} - [(P_{i,t+2}/P_{i,t-1})^{4/3} - 1)]$ where $r_{i,t}^{S}$ is the real interest rate of country i in period t, $i_{i,t}^{S}$ the nominal short-term interest rate and $P_{i,t}$ the GDP deflator.	OECD, "National Accounts", etc.
Nominal long-term interest rate	United States: 10-year treasury notes. Japan: 10-year government bonds. Germany: 10-year government bonds (before 1985Q4, government bonds with maturity of 7–15 years). United Kingdom: 20-year government bonds. France: public and semi-public bonds. Italy: 10-year government bonds. Canada: over 10-year government bonds.	OECD, "Main Economic Indicators", etc.
Nominal short-term interest rate	United States: three-month CD. Japan: three-month CD. (before 1979Q2, two-month bill rate) Germany: three-month interbank rate. United Kingdom: three-month interbank rate. France: three-month PIBOR. Italy: three-month interbank deposit rate. Canada: 90-day deposit rate.	OECD, "Main Economic Indicators", etc.
Accumulated ratio of current accounts to nominal GDP	The accumulated ratio of each term's current accounts to nominal GDP from 1970Q1.	IMF, "International Financial Statistics", OECD, "Main Economic Indicators", etc.

Effects of the global financial crisis on Japanese financial markets in autumn 1998

Data	Content	Source
TIBOR (Tokyo interbank offered rate)	Three-month euroyen TIBOR, three-month euro dollar TIBOR.	Japanese Bankers' Association
LIBOR (London interbank offered rate)	Three-month euroyen LIBOR, three-month euro dollar LIBOR.	The British Bankers' Association
Spot and forward exchange spread	Three-month yen/dollar spot and forward exchange spread.	The Nihon Keizai Shinbun
Yen treasury bill rate	Three-month yen treasury bill.	Japan Bond Trading Co. Ltd
Dollar treasury bill rate	Three-month dollar treasury bill.	US Department of Commerce
Yen/dollar spot turnover, Yen/dollar swap turnover	yen/dollar spot and yen/dollar swap turnover in yen/dollar exchange markets.	Bank of Japan, "Financial and Economic Statistics Monthly"

Bibliography

Bank of Japan (1998): "Annual Review of Monetary and Economic Developments in Fiscal 1997". *Bank of Japan Annual Review*, pp. 57-154.

Bank of Japan (1999): "Tsuuka Oyobi Kinyuu No Chousetsu Ni Kansuru Houkokusho (Report on Money and Market Operations)". June (in Japanese).

Barro R and X Sala-i-Martin (1990): "World Real Interest Rates". *NBER Macroeconomics Annual*, pp. 15-74.

Frankel J (1993): "Quantifying International Capital Mobility in the 1980s", in Frankel, J., *On Exchange Rates*, MIT Press.

French, K and J Poterba (1991): "Investor Diversification and International Equity Markets". *American Economic Review*, 81, pp. 222-6, May.

Fukao, M (1990): "Jissen Zeminaru Kokusaikinyuu (International Economics and Finance)". *Toyo-keizai Sinposha*, (in Japanese).

Hanajiri, T (1999): "Three Japan Premiums in Autumn 1997 and Autumn 1998 – Why did Premiums differ between markets?" *Financial Market Department Working Paper E-series 99-E-1*, August.

Ishi, K (1996): "Jishitsukinri No Ketteiyouin Oyobi Kakkoku-Hikaku Ni Tsuite (The Determinants of Real Interest Rate and Its Comparison among Countries)". *IMES Discussion Paper J-Series 96-J-18*, Institute for Monetary and Economic Studies, Bank of Japan, (in Japanese).

Kang, J and R Stultz (1995): "Why is there a Home Bias? An Analysis of Foreign Portfolio Equity Ownership in Japan". *NBER Working Paper*, No. 5166.

Kawai, M (1994): "Kinyuu Nyumon (Introduction to International Economics and Finance)". *Todai Shuppankai*, (in Japanese).

Mishkin, F (1984): "Are Real Interest Rates Equal Across Countries? An Empirical Investigation of International Parity Conditions". *Journal of Finance 39*, pp. 1345-57, December.

Shirakawa, M (1999): "Nihon No Kokusaisijyou No Kinoukoujyou Ni Mukete (Suggestions for the Improvement of the JGB Market)". *Nihon Ginko Geppo (Bank of Japan Monthly Bulletin)*, June (in Japanese).

Shiratsuka, S and H Nakamura (1998): "Kokusai-Bunsantoushi Niokeru Homu-baiasu-pazuru Wo Meguru Shoronten (The Home Bias Puzzle in International Investment Diversification)". *Monetary and Economic Studies*, 17(2), Institute for Monetary and Economic Studies, Bank of Japan, (in Japanese).

Tesar, L and I Werner (1992):: "Home Bias and the Globalisation of Securities Markets". *NBER Working Paper*, No. 4218.

Monetary policy implications of the international role of the euro

Nuno Cassola[1]

1. Introduction

The international role of the euro is drawing the attention of a growing number of academic and central bank economists. In fact, several studies have already been published focusing particularly on the financial market implications of the emergence of the euro as an international currency.[2] The implications that the internationalisation of the euro might have for the conduct of monetary policy by the Eurosystem have received less attention. These are the focus of this paper.[3] The main difficulty in carrying out such an analysis lies in clearly distinguishing the specific impact of the internationalisation of the euro from other factors that may impact on monetary policy. Factors like the liberalisation and growing international integration of financial markets, and the changes resulting from Monetary Union itself affect the structure of the economy, the behaviour of the private sector and, thus, may impact on monetary policy. Furthermore, technological changes in computing and telecommunications, which occur largely independently but go hand in hand with the increasing international role of the euro, may also have implications for monetary policy. An additional difficulty is related to the lack of data, a fact that inhibits any reasonable empirical exploration of the subject at the current stage. This study, thus, mainly focuses on conceptual and theoretical issues. The paper is organised as follows. Section 2 briefly reviews the current use of the euro by non-euro area residents and the factors that may affect the international use of the euro in the future. Section 3 addresses the impact that the internationalisation of the euro might have on the transmission mechanism of monetary policy (Section 3.1) and on the monetary policy strategy of the Eurosystem (Section 3.2). The latter focuses on money demand (Section 3.2.1), the role of the exchange rate (Section 3.2.2) and the information content of the yield curve (Section 3.2.3). Section 3.3 discusses some aspects relating to financial stability. The general implications of the internationalisation of the euro for monetary policy are summarised in Section 4.

2. The international role of the euro[4]

A currency that performs at least two of its three classical functions – unit of account, medium of exchange and store of value – outside the country or area where it is issued, whether for private or official use, can be considered international money. The euro is the second most widely used currency at the international level, behind the US dollar and ahead of the Japanese yen.[5] This naturally reflects the legacy of the former national currencies of the euro area countries that have been replaced by the

---

[1] Prepared by Nuno Cassola, of the Directorate Monetary Policy (DMP) in the Directorate General Economics (DG-E) of the European Central Bank (ECB). Comments by Philippe Moutot, Wolfgang Schill, Hans-Joachim Klöckers, Klaus Masuch and Nick Vidalis are gratefully acknowledged. The opinions expressed in this paper are those of the author and do not necessarily represent those of the ECB.

[2] See, for example, IMF (1997a), Hartmann (1998) and Portes and Rey (1998).

[3] Discussions on this topic have mainly focused on the incentives to international policy coordination, as, for example, Alogoskoufis and Portes (1997) and Bergsten (1997), and on dollar/euro exchange rate volatility, as, for example, Bénassy-Quéré et al. (1997).

[4] This section benefits from exchanges of views with Philipp Hartmann, in the Directorate General for Research (DG-R) of the ECB, and Adrian Van Rixtel, in the DG-E of the ECB.

[5] For data on the current use of the euro by non-euro area residents, see ECB (1999d).

euro. There are four major factors determining the international role of a currency. The first is history and inertia. One currency tends to be used internationally because others are expected to use it – thus the analogy between the international use of a currency and the choice of English as the international language. This factor militates against a rapid expansion of the international role of the euro. The second is the economic weight of the currency area, particularly in relation to world trade in goods and services. Compared with the United States, the euro area accounts for a greater share of world exports in goods and services, and in terms of GDP per capita the United States and the euro area are comparable. These factors may contribute to the international role of the euro. The third factor is related to financial openness and development of the currency area. In this respect, although the euro area has developed a larger banking sector, equity and debt securities markets are much larger in the United States. The introduction of the euro has fostered a process of structural change in the euro area financial and banking sectors that is expected to contribute to the international role of the euro. The fourth factor is confidence in the value of the currency. The euro might have inherited the reputation of the most stable of the former currencies. Furthermore, the institutional design of the Eurosystem, granting it independence from political interference in pursuing stability-oriented monetary policy, enhances its credibility. Nevertheless, as the practice of central banking shows, only by developing and sustaining a track record of stability will the euro retain or enhance its attractiveness as an international currency.

The four factors mentioned above are related to two underlying economic determinants of the international role of a currency: *size* and *risk*. The first three – history, economic weight and financial development – are related to *size* and interact in a virtuous way to "perpetuate" the dominant position of an international money. Stage Three of EMU acted as a catalyst for wide-ranging transformation in the capital markets of the participating countries. Due to the interplay between network externalities and economies of scale, an integrated euro area capital market will surely exceed the sum of the constituent parts in a fundamental way. In fact, through increased competitiveness and efficiency euro area capital markets will become larger, with increasing liquidity, breadth and depth. This will tend to lower transaction costs (bid-ask spreads) and may facilitate the international use of the euro, which in turn will increase volume of trading in euro financial assets, further reduce transaction costs and, possibly, attract more market participants in a virtuous way. The fourth factor – monetary policy independence and central bank credibility – interacting with the second and the third factors, will to a large extent determine the volatility of returns of euro area financial assets and their correlation with returns on investments denominated in other currencies. These characteristics create opportunities for portfolio diversification across currencies that contribute to reducing exposure to systemic risk and thus act like a "centrifugal" force counteracting the "centripetal" force of the size dimension.

Changes in invoicing and denomination practices in trade, and pricing in standardised and centralised commodity markets are likely to be very slow. Nevertheless, due to lower transaction costs in the foreign exchange market and, perhaps, the increasing ability of euro area exporters to use the euro for invoicing and settlement, it is reasonable to expect a gradual expansion in the use of the euro as a payment/vehicle currency.

The factors mentioned above suggest that the international role of the euro will be determined by market forces in the context of increasing globalisation. There is a two-way relationship between the depth and breadth of euro area financial markets and the international use of the euro.[6] The enlargement of the investor base provided by the internationalisation of the euro is likely to contribute to an expansion of both the quantity and diversity of securities issued by euro area residents. Consequently, trading activity in secondary financial markets could also be stimulated. Of particular relevance could be the development of corporate bond markets and credit derivatives and the impetus given to securitisation. Such feedback from the internationalisation of the euro will contribute to enhancing overall liquidity in euro area capital markets, furthering the reduction of transaction costs. A mutually reinforcing process of financial development and internationalisation could take place. These phenomena may be additional factors in shaping the financial structure in the euro area. In particular, direct finance may gain relevance with a diminished role of banks.

[6] See, for example, McCauley (1997).

3. Potential implications for monetary policy

Financial markets play a key role in the transmission mechanism, as they influence to a large extent the effectiveness of the transmission mechanism of monetary policy. As indicated in Section 2, an enhanced international role of the euro may contribute to the creation of a broader, deeper and more liquid financial market in the euro area. It will be characterised by lower transaction costs, further integrated bond and to some extent equity markets, and possibly an enhanced role of direct finance with a larger role of private debt securities and equity markets. The impact of the international role of the euro on the transmission mechanism will also be determined by the impact of these features on the various channels of the transmission mechanism.

This section discusses the potential implications of the international role of the euro for the conduct of monetary policy by the Eurosystem. Two broad perspectives are taken. Firstly, we discuss the impact that the international role of the euro may have on the transmission mechanism (Section 3.1). Secondly, we focus on whether the international role of the euro might affect the strategy of the monetary policy of the Eurosystem (Section 3.2). Financial stability issues, which are related to both the transmission mechanism and the monetary policy strategy, are discussed in Section 3.3.

3.1 The transmission mechanism of monetary policy

Most economists agree that, in the short run, monetary policy actions can affect real output and other real economic variables. At the same time, in the long run, money is generally considered to be neutral. Nevertheless, there is broad agreement about the important contribution that monetary policy oriented towards maintaining price stability can make to improving economic prospects and raising living standards. There is, though, far less agreement on how precisely monetary policy exerts its influence on the economy (i.e. the transmission mechanism). Due to the diversity of perspectives, this paper does not follow any particular view about the transmission mechanism but, instead, tries to take into account the various approaches that have been put forward in the literature.[7] After briefly reviewing the theoretical basis for considering the different mechanisms, this section discusses whether and how these might be affected by the internationalisation of the euro.

There are several channels through which changes in money and interest rates flow through to aggregate demand. These channels include interest rate effects, exchange rate effects and wealth effects. Furthermore, one can make a distinction between the credit channel and the interest rate channel that is mainly concerned with whether banks and bank lending play a special role in the transmission mechanism.

Brief overview of the transmission mechanism

Monetary policy tightening is generally associated with a reduction of base money supply growth and higher short-term nominal interest rates. Given price or inflation stickiness,[8] following an increase in nominal short-term interest rates real short-term interest rates rise as well. Additionally, longer-term real interest rates might also rise slightly.[9] These higher real interest rates change the opportunity cost

---

7 For a brief overview of the transmission mechanism, see, for example, Mishkin (1995) and the papers included in the *Journal of Economic Perspectives*, Vol. 9 (1995): 3-96. See also Dale and Haldane (1993) and IMF (1996). For a recent and comprehensive survey, see Walsh (1998).

8 When prices are fully flexible, anticipated monetary policy might still impact on real activity. For example, anticipated inflation, which acts like a tax on real balances, reduces the utility of the representative agent. Fully flexible price models will not be considered in this paper because of the weak empirical evidence supporting them. See Walsh (1998).

9 Central bank credibility will be an important factor in the transmission mechanism. For example, if longer-run inflation expectations are not firmly anchored, nominal interest rate changes may not be considered by the private sector as changes in the real interest rate and consequently the private sector may not alter its demand for investment and/or consumption. Furthermore, as central bank credibility may be subject to changes, the transmission mechanism may also vary over time. This might be of particular relevance in the case of the internationalisation of the euro because the Eurosystem's policy actions will have to be understood by investors resident outside the euro area. These investors may

of borrowing funds to finance expenditure and will tend to lead to a decline in investment and, perhaps, consumption demand, which produces a decline in aggregate demand and output.[10] The intensity of these effects will depend on the extent of the transmission of official interest rate changes along the yield curve and on the degree of the transmission of market interest rate changes to retail deposit and loan interest rates.

An increase in official interest rates may also cause a decline in asset prices (equity, property), by changing the discount rate of future earnings from holding assets. As a consequence, the market value of firms will tend to fall in relation to the replacement cost of capital (Tobin's q) and firms will have less incentive to buy new investment goods because through takeovers they can buy existing capital more cheaply. Investment spending would thus be reduced. Wealth effects will also tend to lower private consumption.

Furthermore, the quantitative importance of changes in interest rates via cash flow effects will depend on the leverage of the private sector and on the balance between short- and long-term debt in the liabilities of firms (and the asset of households) and the mixture of fixed versus floating rate debt. Generally, demand will be affected via cash flow effects of changes in interest rates in so far as borrowers and lenders have different marginal propensities to spend.

Banks may also play a special role in the transmission mechanism (credit channel) to the extent that they are particularly well suited to deal with the problem of screening and monitoring borrowers that have limited access to capital markets (small or new firms and households).[11] When monetary policy tightening leads to decreasing bank reserves and higher funding costs, banks will reduce the supply of lending if loans and securities are not perfect substitutes.[12] With banks reducing credit and firms unable to easily substitute from bank loans to other sources of credit or retained earnings, the availability of bank lending may have an independent impact on aggregate spending, reinforcing the impact of interest rate increases. Spending in consumer durable goods and housing purchases may also be affected for similar reasons. The usual assumption in the literature is that if it exists, the bank lending effect enhances the efficacy of monetary policy.

Asset price changes may lead to a decline in the net worth of firms, meaning that lenders, in effect, have less collateral for their loans. Consequently, banks will be less protected against shocks to borrowers' balance sheets and against moral hazard, which may lead to decreased willingness of banks to lend to firms.[13] An increase in official interest rates also causes deterioration in firms' balance sheets because it reduces net cash flow, possibly at the time when retained earnings decline. The balance sheet effect will imply a more fragile financial position of the private sector and an increased likelihood of financial distress that leads to a decline in spending in investment.

The role of the exchange rate in the transmission mechanism can be briefly summarised. Higher domestic (real) interest rates normally lead to an appreciation of the currency. The higher value of the currency makes goods produced in the country relatively more expensive than foreign goods, thereby causing a fall in net exports and hence in aggregate demand. Furthermore, currency appreciation will tend to lower import prices expressed in domestic currency, thus further dampening inflationary pressures in the economy.

---

have less information about euro area economic developments than residents or may have different views about the implications of the Eurosystem's monetary policy actions.

10 The overall impact of interest rate changes on consumption is theoretically ambiguous due to offsetting income and substitution effects.

11 In reality there is a spectrum of firms, from small to large, in the economy. With the deepening, broadening and greater liquidity of euro capital markets, partly resulting from the internationalisation of the euro, more medium-sized firms may actually gain access to capital markets.

12 If they were perfect substitutes, banks would sell securities to maintain loan volumes.

13 It does not imply quantitative credit rationing by banks. Price rationing through higher premiums over money market interest rates and/or other non-price borrowing terms (more collateral) may lead to a decrease in borrowing.

When discussing the implications of international capital market integration for US monetary policy, it is frequently emphasised that the internationalisation of finance changed the transmission mechanism by changing the effects of actual and anticipated exchange rate movements and thus enhancing the role of the exchange rate.[14]

The impact of the internationalisation of the euro on the transmission mechanism: general aspects

(i) Quicker adjustment of market interest rates to official interest rate changes and more competition in banking

Should the internationalisation of the euro stimulate the development of a financial structure more dominated by direct finance, interest rates and wealth effects could gain more relevance in the transmission mechanism, because financial market prices tend to react more rapidly to official interest rates than retail deposit and lending rates. Furthermore, facing increased competition, banks may have to adjust their rates more promptly by changing interest rate spreads.

One can argue that it may become easier for domestic banks to attract funds from outside the euro area, for example through the issuance of certificates of deposit, or to securitise their assets, for instance mortgages. However, the ECB will continue to have sufficient control over short-term euro rates. Thus, banks would have to borrow in foreign currency if they would like to avoid higher rates, thus incurring exchange rate risks. Consequently, it is unlikely that the sensitiveness of banks' assets and liabilities to monetary policy actions will be significantly affected by availability of funds from non-residents.

Naturally, the internationalisation of the euro does not change the asymmetric information problem that is at the root of the "special" role of banks. Thus, if the problems of screening and monitoring borrowers are not significantly affected by the internationalisation of the euro, small firms and households will continue to be constrained in their access to the (euro) capital markets. By contrast, for larger firms access to external finance will tend to be easier and less costly. Consequently, the internationalisation of the euro may accentuate the differences in the ways in which the different sectors of the economy react to changes in monetary policy. Additionally, for small firms and households, the international role of the euro is unlikely to be, in itself, a factor fostering major breaks in existing borrower-lender relationships.

(ii) Higher interest rate sensitivity of the economy

It also seems that the main factors that determine the strength of the interest rate channel in the transmission mechanism are largely independent of the internationalisation of the euro. For example, increasing long-term borrowing at fixed rates by euro area firms might reflect expectations of price stability or stem from structural changes in euro area capital markets resulting from Stage Three of EMU.[15]

The internationalisation of the euro, however, may have an indirect effect on the interest rate channel. For example, if third countries successfully peg their exchange rates to the euro, there will be a stronger impact of changes in euro area interest rates on interest rates outside the euro area. This in turn will have an impact on economic activity in these countries. Through its effect on euro area exports to these countries, the interest rate channel will be reinforced, depending on the importance of the trade relations of the euro area with the countries that tie their exchange rates to the euro.

The transmission process of monetary policy via feedback effects through third countries will also be influenced by the role of the euro as an international investment currency and by the respective net asset position of other countries. For example, if a foreign country uses the euro mainly for the denomination of short-term or floating debt, higher euro short-term rates would tend to dampen demand in that country. This effect will be compounded if borrowers or banks in these countries rely

14 See, for example, Friedman (1988), IMF (1997a) and Obstfeld and Rogoff (1995).

15 Naturally, long-term borrowing at fixed interest rates will tend to shield debtors and creditors from changes in short-term interest rates and thus, ceteris paribus, may reduce the efficacy of the cash flow effect of changes in interest rates.

heavily on the euro, whereas their assets are denominated in their local currency, in particular if the latter significantly depreciates against the euro. The indirect impact of these developments on euro area developments would again mainly depend on the degree of trade relations of the euro area with the respective country.

(iii) Weaker exchange rate channel

An extensive use of the euro as invoice currency and as currency of denomination and settlement in commodity markets could make the euro area HICP less sensitive, in the short run, to US dollar exchange rate movements. Under these circumstances commodity price movements would convey a better signalling of relative price changes for euro area producers and consumers and may help focus attention on the more fundamental and persistent factors underlying price trends. A widespread use of the euro as currency of denomination in commodity markets or as invoice currency could also influence the effects of exchange rate changes on the current account. If euro area exports and imports are increasingly invoiced in euros, the short-term effects of exchange rate changes on the trade balance should in general be reduced.

3.2 The monetary policy strategy of the Eurosystem

The primary objective of the Eurosystem is to maintain price stability in the euro area, as laid down in the Treaty on European Union. To fulfil its mandate, the Governing Council of the European Central Bank has adopted a monetary policy strategy that is neither conventional monetary targeting nor direct inflation targeting nor a simple mixture of the two.[16] It is comprised of three elements: the announcement of a quantitative definition of price stability (year-on-year increase of the HICP for the euro area below 2%) and the so-called two pillars. The first pillar gives money a prominent role.[17] The second is a broadly based assessment of the outlook for price developments. Given that inflation is ultimately a monetary phenomenon, monetary aggregates should provide a "nominal anchor" for monetary policy. Thus, a quantitative reference value of 4.5% for the growth rate of M3 was announced in December 1998. The second pillar of the strategy comprises an analysis of a wide range of indicator variables as well as the use of various forecasts of the outlook for price developments.[18]

In devising its strategy, the Eurosystem explicitly acknowledged that EMU represents an important regime shift. Therefore, the uncertainty facing the Eurosystem concerning the indicator properties of monetary, financial and other economic variables for future price developments, and regarding private sector reaction to monetary policy actions, is larger than has typically been the case in national contexts in the past. Against this background, the Eurosystem eschews relying on a single indicator or intermediate target for the conduct of monetary policy.

The strategy aims at identifying those economic disturbances that threaten price stability and prompting a monetary policy response which is appropriate to both the prevailing economic circumstances and the nature of the threat.

This section discusses whether the international role of the euro might affect the monetary policy strategy of the Eurosystem. It should be mentioned at the outset that the discussion does not aim at providing a comprehensive review of the implications for all aspects of the strategy. Instead, the arguments reviewed have a narrower perspective centred on the monetary and financial aspects and implications of the strategy. Therefore, a balanced review of the likely implications of internationalisation of the euro for the two pillars of the monetary policy strategy of the Eurosystem is not undertaken in this paper.

---

[16] For a detailed exposition of the monetary policy strategy of the Eurosystem, see ECB (1999a).

[17] See ECB (1999b).

[18] See ECB (1999c).

3.2.1 Stability of money demand

As mentioned in its monetary policy strategy, the ECB gives a prominent role to money with the announcement of a reference value for the growth of a broad monetary aggregate (M3). A question arises as to whether the growing internationalisation of the euro might have an impact on the stability and the information content of monetary aggregates, in particular of M3.

There is an extensive literature on the factors that may, in general, affect the indicator properties of money and its implications for the conduct of monetary policy.[19] Currency substitution and changes in euro deposits held outside the euro area are factors that may impact on the signals of monetary aggregates.

(i) Currency substitution in third countries

With its internationalisation the euro may play an enhanced role in some countries outside the euro area, leading in particular to currency substitution in third countries. To the extent that it is held as euro-denominated deposits by non-euro area residents, the broad aggregate M3 is not affected directly, as this aggregate only comprises holdings of euro area residents. Only the demand for euros in foreign countries will directly impact on M3.[20] However, as the M3 aggregate covers a broad range of financial assets, the share of currency in circulation is relatively small. At the end of May 1999, it amounted to only 7%. While increases in banknotes in circulation abroad may affect the narrow monetary aggregate M1, such currency substitution is less likely to be a major source of concern regarding the interpretation of the information content of the broad aggregate M3 in the euro area unless it occurs very suddenly and, at the same time, no information on the reason for the higher currency demand is available.

(ii) More holdings by residents abroad

The internationalisation of the euro may also take the form of increased holdings by residents of euro-denominated deposits abroad. Such holdings may be driven by differences in taxation or other regulatory measures between euro area and non-euro area countries. It is a priori unclear whether such holdings should be ideally considered to be part of M3. On the one hand, the fact that they have similar liquidity characteristics as holdings of comparable deposits within the euro area would call for their inclusion in a monetary aggregate. On the other hand, experience tells that such deposits are often not held for transaction purposes and may therefore be less relevant for the assessment of risks for price stability. At the present stage, however, it is reassuring for the Eurosystem that the current definition of M3 (i.e. deposits linked to holdings in the euro area) shows encouraging signs for stability and indicator properties. Hence, from this argument, it is unclear whether aggregates extended to including deposits abroad would imply better empirical properties than that of the current development of M3. Still, it is desirable that the Eurosystem have a good statistical basis on which to analyse the implications of the international role of the euro.

(iii) Analysis of counterparts

Counterparts of M3, such as lending by domestic MFIs to euro area residents, may entail useful information regarding prospective developments in activity and prices. Nonetheless, an increased internationalisation of the currency may impact on the relationship between domestic MFIs' lending to euro area residents and domestic activity. For instance, an increased international role of the euro may lead to increased lending by euro area MFIs to borrowers outside the euro area. This lending would appear under the external assets item in the balance sheet of the euro area MFIs.

---

[19] See, for example, Friedman (1993) and Goodhart (1989).

[20] The demand by non-residents for money market fund shares/money market paper and debt securities up to two years, whose total share in M3 amounts to 10%, will also affect M3. Due to lack of detailed statistical information, it is not currently possible to separately identify and net out the amounts held outside the euro area by non-residents.

Conclusions on the role of money in the strategy

Overall, the role of money in the monetary policy strategy of the Eurosystem can well accommodate the challenges that the growing international role of the euro might bring with respect to the development of monetary aggregates. Indeed, when devising its strategy, the Eurosystem took into account that the growth of monetary aggregates might be affected by structural changes and behavioural and statistical uncertainties, such as internationalisation, which are associated with the shift in regime that represents the move to Stage Three of EMU. Against this background, for the reference value a broad monetary aggregate (M3) was chosen that includes a wide spectrum of deposits, as well as close substitutes for them such as marketable short-term bank liabilities, and thus is less affected by portfolio shifts. Moreover, the concept of a reference value does not mean that the Eurosystem will change its policy stance or react in a mechanical way to deviations of M3 growth from the reference value. A careful analysis of the reasons behind monetary developments always needs to be carried out before drawing policy conclusions. This analysis includes an investigation of the flow of funds, and of the counterparts and components of M3. One issue arising from the internationalisation of the euro is therefore, probably, the availability of high-quality statistics on international, and in particular euro area residents', holdings of euros abroad. Such statistics are essential for the thorough analysis of monetary developments that is needed to assess the appropriateness of current definitions of monetary aggregates and risks for future price stability.

3.2.2 The role of the exchange rate

(i) Exchange rate policy of the Eurosystem

From the perspective of monetary policy, there are two main lessons from the experience with floating exchange rates. First, that flexibility in the exchange rates of the major currencies is needed to cope with the shocks that drive the dynamics of the world economy; and also because of the differences in the structural characteristics of the major world economies. Secondly, that the most important factor in promoting exchange rate stability is the maintenance of sound macroeconomic policies directed towards non-inflationary long-run growth and avoiding large external imbalances.

While, in line with its strategy, the Eurosystem takes exchange rate developments into account, it eschews implicit or explicit exchange rate objectives and mechanistic reactions to exchange rate movements. Rather, the strategy emphasises the need to analyse the nature of shocks hitting the euro area economy, in order to decide on the appropriate monetary policy response aimed at maintaining price stability. Any attempts to introduce certain types of exchange rate objectives would, in many circumstances, constrain the pursuit of a stability-oriented monetary policy. In other words, the exchange rate policy cannot be separated in a meaningful way from monetary policy; rather, it has to be consistent with the overall monetary policy strategy.

The Treaty sets a clear division of responsibilities between governments and monetary authorities in the conduct of economic policy in the euro area. The Eurosystem is responsible for maintaining price stability in the euro area.[21] The Stability and Growth Pact and the "no bailout" clause set the right incentives for the conduct of sound and disciplined fiscal policies across all participating Member States. The separation of responsibilities in policy-making and the clear emphasis on price stability and sound public finances greatly enhance the transparency and accountability of policy-making in general, and in particular the credibility of the Eurosystem.

(ii) Pegging to the euro by third countries

It seems plausible that in the future additional countries will consider anchoring or decide to anchor their currency either formally or informally to the euro or to a basket of currencies in which the euro is a major component. Given the prospects of EU enlargement, visible changes are likely to take place in this area in the foreseeable future. It may even transpire that third countries decide to introduce the

---

[21] The Treaty also states that general economic policies in the Community shall be supported by the Eurosystem, without prejudice to the objective of price stability.

euro as their legal tender, outside the procedure foreseen in the EC Treaty ("euroisation"). Against this background, it is crucial that the Eurosystem's focus on maintaining price stability in the euro area be absolutely clear and credible, irrespective of the role the euro plays in third countries. If that were not the case, i.e. if financial markets were to doubt the strict focus of the ECB on euro area price stability, any major economic development in those countries that peg to the euro (or even introduce it as legal tender) could have an immediate, and possibly undesirable, impact on euro interest and exchange rates. Such a spillover could be particularly severe if a major banking/financial crisis in countries with a currency board peg to the euro (or with the euro as legal tender) became likely or actually occurred.

Against this background, in line with the strategy, the policy of the Eurosystem should be designed in a way which shields the credibility of the Eurosystem against external shocks, thereby avoiding such spillovers and continuing to provide the Eurosystem with as much room for manoeuvre as possible. For the pegs to the euro to be sustainable, these countries will have to have a sound banking system, follow credible and sound monetary and fiscal policies and enhance, through structural reforms, the flexibility of their product and labour markets. Normally, the closer the exchange rate link, the more important it is that these preconditions be fulfilled. This is particularly the case for currency boards (and even more so for "euroisation"). Only in this way may euro anchoring by third countries allow the benefits of price stability to be extended well beyond the euro area, based on a very credible focus of the ECB on price stability in the euro area.

3.2.3 The information content of the yield curve

The Eurosystem analyses interest rates in general and the yield curve in particular as one indicator in its broadly based assessment of the outlook for price developments in the euro area. Many authors consider the term structure of interest rates as a good indicator of market expectations or of the relative degree of tightness of monetary policy.[22] A few stylised facts can be drawn from the empirical evidence for the US and European economies. Firstly, an increase in official interest rates tends to flatten the yield curve, and the extent of the flattening depends on the credibility of the central bank. Secondly, the slope of the yield curve has been shown to often possess leading indicator properties for turning points in the business cycles; and thirdly, the yield curve contains information about future inflation. Moreover, interest rates and the yield curve are important determinants of the developments of monetary aggregates and their counterparts. Thus, the yield curve also plays an important role in the analysis of monetary growth relative to the reference value.

Generally, the predictive power of the yield curve for output and inflation should be stronger for countries that are large and have an independent monetary policy. A country that pegs or manages its exchange rate within some (implicit) target zone may have much less influence on the term structure because domestic interest rates will be extremely sensitive to interest rates in the foreign country and to market perceptions of the credibility of the peg (or of the target zone). Therefore, given that the Eurosystem has no exchange rate target, there is reason to assume, a priori, that the yield curve may contain important information for monetary policy in the euro area.

Domestic and foreign investors may react in different ways to expected changes in real returns. Deviations from purchasing power parity may drive a wedge between the real rate of return on domestic assets that is relevant for domestic residents and the real rate of return that is relevant from an international perspective. For a resident in the euro area, an expectation of lower ECB rates will not necessarily lead to a decrease in the expected short-term real return on euro area assets measured in terms of the domestic consumption bundle. This would happen, for example, if lower ECB rates were accompanied by lower short-term inflation expectations. For a non-resident, though, there may be a decrease in the expected real return of euro area assets measured in terms of the foreign consumption bundle because the euro exchange rate may be expected to depreciate by more than the inflation differential. This may entail differentiated portfolio reactions of domestic and international investors that may impact on the reaction of the euro yield curve to expected monetary policy.

---

[22] For a brief survey with particular reference to the ECB, see Estrella and Mishkin (1997).

However, these factors seem to be of second-order relevance also because an increased international use of the euro as investment/financing currency would normally deepen the market for euro-denominated assets and thus increase liquidity. This implies that a portfolio shift of a given size (e.g. if one big investor sells a certain large amount of euro bonds) would impact less on euro interest rates. The empirical evidence for the United States suggests that changes in the indicator properties of the yield curve are perhaps more related to changes in the strategy of monetary policy and credibility (e.g. October 1979) than to the international role of the dollar. Nevertheless, the Eurosystem's policy actions will have to be understood by investors resident outside the euro area. These investors may have less information about euro area economic developments than residents or may hold different views on the implications of the Eurosystem's monetary policy actions. Thus an extended international role of the euro poses challenges to the communications policy and transparency of the Eurosystem.

3.3 Financial stability[23]

The strength of the financial system is an important feature of the economic environment in the monetary policy analysis. For example, a soundly capitalised banking sector will be able to provide "distress finance" for companies that suffer temporary cash flow problems, thereby stemming the tide of bankruptcy and stabilising the economy. In contrast, weak banks may be forced to ration credit and recall loans, thereby increasing the risk of a deflationary spiral following a weakening in aggregate demand. Thus, the strength of the banking sector and its ability to absorb the costs implied by a rising proportion of non-performing loans on its balance sheet, are a crucial determinant of the impact of monetary policy actions.

As mentioned, in the euro area the banking sector still has a predominant role in the financial system. Therefore, financial stability considerations in the euro area are closely linked to the stability of the banking sector. Against this background, the structural changes in the banking sector fostered by the increasing international role of the euro may impact on financial stability. It can be argued that adverse developments (boom and bust) might result from these expected structural changes. The factors that might contribute to such developments include changes in the financial system such as securitisation, disintermediation and the role of institutional investors and advances in computation and information technology (e.g. internet banking). Also the fragmented nature of the euro area banking sector as well as the likely overcapacity in the sector are further factors contributing to potential weakening of the banking system in the euro area. The growing internationalisation of the euro works as a catalyst for these pressures for change, and therefore may deepen these structural changes.

From the financial stability point of view, the most worrying scenario would be one in which banks respond to these pressures by attempting to increase their revenues (that could otherwise decline) in an unsustainable manner. In practice, it could lead to more risk-taking, also in the form of more relaxed lending standards, which in turn would have the potential to fuel an asset price boom, and increase the vulnerability of the economy to asset price fluctuations. Indeed, if this kind of development were to get under way, it could lead to a boom-and-bust type of development in asset markets.

Financial stability may impinge on the effectiveness of monetary policy. If, for example, the balance sheets of the private sector are weak, the effectiveness of monetary policy will tend to be reinforced. Furthermore, changes in the strength of private sector balance sheets can lead to changes in the impact of a given level of interest rates. However, if a central bank indicates with its announcements or even with its actions that it is generally concerned about financial stability when it is setting interest rates, the private sector will take it into account ex ante. As the central bank is expected to react in an accommodating way in the case of financial stress, effectively providing financial markets with insurance against large losses, it can reinforce risk-taking by the private sector, producing asset price "bubbles". It may also raise the probability that subsequent large corrections in asset prices will occur.

Against this background, a central bank should not push market participants into the belief that it will react in an accommodating way to weakening private sector balance sheets and asset price volatility.

[23] This section draws on joint work with Klaus Tuori of the DMP in the DG-E of the ECB.

In fact, incentives for market discipline would become ineffective, as it is already limited by the deposit insurance system and explicit government guarantees for banks or implicit in the “too large to fail” problem.

Monetary policy, however, does not act in isolation. In certain circumstances, misguided structural policies and/or fiscal policies create incentives for private sector behaviour that distort the allocation of resources and may lead to financial instability. For example, tax systems that create incentives for leveraged acquisition of real estate may generate unsustainable asset price movements. Similarly, failures in prudential regulatory policies or in the conduct of financial supervision can create incentives or allow excessive risk-taking among financial market participants, which could make them unduly exposed to asset price movements. Therefore stability-oriented monetary policy can only yield its positive implications for financial stability if these other elements of the financial stability framework are in place.

4. Conclusions

At this stage it is difficult to evaluate the size and direction of the impact of the international role of the euro on the transmission mechanism. However, as the international role of the euro will enhance the role of financial markets in the transmission mechanism, their rapid response to monetary policy changes might contribute to a reduction in the transmission mechanism lags.

Overall, it should be emphasised that it is very unlikely that the strategy of the Eurosystem would have to be changed in response to the increasing international role of the euro, as it allows for these effects to be taken into account.

An enhanced international role of the euro may increase the demand for euro banknotes in third countries. Nevertheless, it may not significantly affect the growth of M3, given that the share of currency in circulation in M3 is relatively small compared to other components. There are currently no signs that the above disturbance is occurring. But should the information content of M3 or counterparts be influenced by the international role of the euro, this would not be a major concern as long as these influences could be taken into account in the regular analysis of monetary developments and be clearly explained to the public. Moreover, it should be considered that a monetary policy which maintains price stability in a credible way not only enhances the international role of the euro, but also contributes to the stability of money demand and makes it easier to assess the information content of monetary and financial indicators.[24]

Despite the role that the euro might play in third countries, it is crucial that the Eurosystem’s focus on maintaining price stability in the euro area remain absolutely clear and credible. Otherwise moral hazard problems may emerge. If a central bank indicated either explicitly or implicitly that it intended to react to asset price movements in the euro area fostered by the international role of the euro, this would encourage risk-taking, even leading to asset price bubbles.

The moral hazard problem discussed above does not imply that a central bank should not be concerned about domestic financial price developments as well as economic and financial developments in third countries. However, it should be made clear these developments are not monetary policy objectives but rather factors or constraints to be assessed and taken into account in the conduct of monetary policy. Clearly, in order to focus on price stability in the euro area, the Eurosystem would need to evaluate the impact of its own actions on third countries and financial markets.

To conclude, the international role of the euro would not alter the ability of the Eurosystem to maintain price stability over the medium term. A key precondition for this conclusion is a continuation of the floating exchange rate regime for the euro, with the absence of intervention commitments.

---

[24] See Issing (1997).

Bibliography

Alogoskoufis, George and Richard Portes (1997): “The Euro, the Dollar and the International Monetary System”. Paper prepared for IMF (1997a): *EMU and the International Monetary System*, Conference, 17-18 March, Washington D.C.

Baliño, Tomás et al. (1997): *Currency Board Arrangements, Issues and Experiences.* Occasional Paper, IMF.

Bank for International Settlements (1995): *Financial Structure and the Monetary Transmission Mechanism.* Basel.

Bénassy-Quéré, Agnès, Benoît Mojon and Jean Pisani-Ferry (1997): “The Euro and Exchange Rate Stability”. Paper prepared for IMF (1997a): *EMU and the International Monetary System*, Conference, 17-18 March, Washington D.C.

Bergsten, Fred (1997): “The Impact of the Euro on Exchange Rates and International Policy Coordination”. Paper prepared for IMF (1997a): *EMU and the International Monetary System*, Conference, 17-18 March, Washington D.C.

Dale, Spencer and Andrew Haldane (1993): “Bank Behaviour and the Monetary Transmission Mechanism”. *Bank of England Quarterly Bulletin*, November, pp. 478-91.

Dotsey, Michael (1996): “Changing Policy Orientation in the United States”, in Siebert, Horst (ed.), *Monetary Policy in an Integrated World Economy*, Symposium, 1995, Institut für Weltwirtschaft an der Universität Kiel, Mohr Tübingen, pp. 95-113.

Estrella, Arturo and Frederic Mishkin (1997): “The Predictive Power of the Term Structure of Interest Rates in Europe and the United States: Implications for the European Central Bank”. *European Economic Review*, 41(7), pp. 1375-1401.

European Central Bank (1999a): “The stability-oriented monetary policy of the Eurosystem”. *Monthly Bulletin*, January.

European Central Bank (1999b): “Euro area monetary aggregates and their role in the Eurosystem’s monetary policy strategy”. *Monthly Bulletin*, February.

European Central Bank (1999c): “The role of short-term economic indicators in the analysis of price developments in the euro area”. *Monthly Bulletin*, April.

European Central Bank (1999d): “The international role of the euro”. *Monthly Bulletin*, August.

Federal Reserve Bank of Kansas City (1989): *Monetary Policy Issues in the 1990s.* Symposium.

Federal Reserve Bank of Kansas City (1993): *Changing Capital Markets: Implications for Monetary Policy*. Symposium.

Friedman, Benjamin (1988): “Lessons on Monetary Policy from the 1980s”. *Journal of Economic Perspectives*, 2(3), pp. 51-72.

Friedman, Benjamin (1993): “The Role of Judgement and Discretion in the Conduct of Monetary Policy: Consequences of Changing Financial Markets”, in Federal Reserve Bank of Kansas City, *Changing Capital Markets: Implications for Monetary Policy*. Symposium.

Goodhart, Charles A E (1989): “The Conduct of Monetary Policy”. *Economic Journal*, 99 (396), pp. 293-346; reprinted in Goodhart, Charles A E (1995): *The Central Bank and the Financial System*, Macmillan, London, Ch. 6, pp. 93-141.

Goodhart, Charles A E (1992): “The Objectives for, and Conduct of, Monetary Policy in the 1990s”, in Blundell-Wingnall, A (ed.), *Inflation, Disinflation and Monetary Policy*, Sydney, Reserve Bank of Australia: pp. 314-33; reprinted in Goodhart, Charles A E (1995): *The Central Bank and the Financial System*, Macmillan, London, Ch. 10, pp. 216-35.

Goodhart, Charles A E (1995): *The Central Bank and the Financial System.* Macmillan, London.

Goodhart, Charles A E (1996): “Financial Globalisation, Derivatives, Volatility”, in Siebert, Horst (ed.), *Monetary Policy in an Integrated World Economy*, Symposium, 1995, Institut für Weltwirtschaft an der Universität Kiel, Mohr Tübingen, pp. 61-90.

Hartmann, Philipp (1998): *Currency Competition and Foreign Exchange Markets: The Dollar, the Yen and the Euro.* Cambridge University Press, Cambridge.

International Monetary Fund (1996): “Policy Challenges Facing Industrial Countries in the Late 1990s”. *World Economic Outlook*, October, Ch. III, pp. 42-56.

International Monetary Fund (1997a): *EMU and the International Monetary System.* Conference, 17-18 March, Washington D.C.

International Monetary Fund (1997b): “Meeting the Challenges of Globalisation in the Advanced Economies”. *World Economic Outlook*, May, Ch. III, pp. 59-71.

International Monetary Fund (1999): “International Financial Contagion”. *World Economic Outlook*, May, Ch. III, pp. 66-87.

Issing, Otmar (1996): “Is Monetary Targeting in Germany Still Adequate?” in Siebert, Horst (ed.), *Monetary Policy in an Integrated World Economy*, Symposium 1995, Institut für Weltwirtschaft an der Universität Kiel, Mohr Tübingen, pp. 117-30.

Issing, Otmar (1997): “Monetary Targeting in Germany: The Stability of Monetary Policy and of the Financial System”. *Journal of Monetary Economics* 39, pp. 67-79.

Krugman, Paul (1984): “The international role of the dollar: theory and prospect”, in Bilson, J and R Marston (eds.): *Exchange Rate Theory and Practice*, Chicago University Press, Chicago, pp. 261-78.

McCauley, Robert N (1997): *The Euro and the Dollar. BIS Working Papers* No. 50, Basel.

Mishkin, Frederic S (1995): “Symposium on the Monetary Transmission Mechanism”. *Journal of Economic Perspectives*, 9(4), pp. 3-10.

Obstfeld, Maurice and Kenneth Rogoff (1995): “The Mirage of Fixed Exchange Rates”. *Journal of Economic Perspectives*, 9(4), pp. 73-96.

Portes, Richard and Hélène Rey (1998): “The Emergence of the Euro as an International Currency”. *Economic Policy*, 26, pp. 307-43.

Siebert, Horst (ed.) (1996): *Monetary Policy in an Integrated World Economy*, Symposium 1995,. Institut für Weltwirtschaft an der Universität Kiel, Mohr Tübingen.

Walsh, Carl E (1998): *Monetary Theory and Policy.* MIT Press, Cambridge (Mass.).

Williamson, John (1985): *The Exchange Rate System.* Institute for International Economics. Washington D.C.

Williamson, John (1995): *What Role for Currency Boards?* Institute for International Economics, Washington D.C.

Williamson, John and Marcus Miller (1987): *Targets and Indicators: A Blueprint for the International Coordination of Monetary Policy.* Institute for International Economics, Washington D.C.

Wyplosz, Charles (1997): “An International Role for the Euro?” Report to European Capital Market Institute.

Increasing integration of applicant countries into international financial markets: implications for monetary and financial stability

Jarko Fidrmuc and Franz Schardax[1]

1. Introduction

Growing integration of international financial markets entails an increase in financial flows between economies. Deeper integration into international financial markets can provide important benefits: access to foreign capital eases financing constraints for investment projects and thus increases economic growth. Besides the direct impact of additional resources, capital inflows often have positive externalities, such as spillovers of managerial and technical know-how, especially in the case of FDI. However, increasing capital flows also pose additional challenges for central banks. Capital inflows can have inflationary effects and can increase the vulnerability of an economy's financial system. Capital flow reversals may trigger financial crises. This paper analyses these aspects for four advanced transition economies (the Czech Republic, Hungary, Poland and Slovenia), widely expected to be among the first central and eastern European countries to join the European Union. The issue of financial integration is thus highly relevant for this group of countries.

In this paper we define monetary stability as price stability, and financial stability as an absence of financial crises. Our definition of financial crises is based on that of Kaminsky and Reinhart (1998), who distinguish between balance of payments crises[2] and banking crises. Balance of payments crises are characterised by "events" such as devaluations/flotations of the exchange rate and/or losses of official reserves in connection with large increases in interest rates. Banking crises include the closure, merger or takeover by the state of one or more financial institutions as a consequence of bank runs. If no bank run occurs, the closure, merger or takeover of or provision of large-scale government assistance to an important financial institution (or group of institutions) that marks the start of a string of similar outcomes for other financial institutions is also subsumed under the term "banking crisis". On many occasions, both types of crisis are strongly interlinked, a situation we will call a "twin crisis".

The paper is organised as follows. Section 2 deals with the impact of capital inflows on monetary developments. It starts with a brief overview of macroeconomic effects of capital inflows, with an emphasis on the impact of capital inflows on the current account in the Czech Republic, Hungary, Poland and Slovenia. Based on this brief theoretical introduction, we present stylised facts on the influence of capital flows on exchange reserves and monetary aggregates in CEECs. Section 3 investigates the impact of various kinds of capital inflows and other variables on the development of inflation in Hungary. For reasons of data availability, this analysis could be undertaken only for Hungary. Next, we turn to issues of financial stability (Section 4). We briefly discuss how capital inflows can pose a threat to financial stability. Subsequently, we analyse the development of several financial indicators in the accession countries that Kaminsky and Reinhart (1999) as well as Kaminsky et al. (1998) identified as the most reliable early warning signals of financial crisis. Finally, Section 5 contains conclusions about monetary and financial stability.

---

1 We would like to thank Maria Dienst and Andreas Nader for excellent statistical support. We are also very grateful for helpful comments from Peter Mooslechner, Peter Backe, Kurt Pribil and Doris Ritzberger-Grünwald.

2 The term "currency crisis" is also often used for this kind of crisis in the literature.

2. Impact of capital flows on monetary development

2.1 Macroeconomic effects of capital flows

Whereas inflows of foreign direct investment had been small at the beginning of transition, an increase has been recorded recently. According to the World Investment Report 1999 (UNCTAD (1999)), the CEECs have been catching up with the rest of the world since 1993. Moreover, other forms of capital flows (portfolio investment) have started to develop dynamically in recent years. However, the capital inflows are heavily concentrated on only a few countries in the region. It is no coincidence that the Czech Republic, Hungary, Poland and Slovenia are generally seen as the best-performing countries in the region and the countries which are most likely to join the European Union in the near future.

From a balance of payments point of view, a surplus in the financial account (which is equivalent to a capital inflow) will automatically be accompanied by a deficit in the current account and/or an increase in official reserves. A current account deficit can result from imports of investment goods, including modern equipment. In such a case, capital inflows finance an enlargement or upgrade of production capacities, which has positive effects on the trade balance and the current account due to increased export opportunities and/or import substitution after completion of the investment. Furthermore, imports of investment goods are expected to adjust relatively quickly to the changed economic situation in the event of a reversal of capital flows, without causing significant welfare effects. Conversely, imports financed by capital inflows may be used for increased private consumption. Calvo et al. (1995) note that capital inflows to the CEECs were largely used to finance consumption growth between 1990 and 1993. This is also documented in Table 1. The current account deficit is more frequently associated with real growth of private consumption than with an increase in capital formation. This can be seen in a relatively high and negative correlation between the current account (as a share of GDP) and private consumption.

The development of the current account, consumption and investment exhibits different patterns in the CEECs covered by this study. In the Czech Republic, the real decline of both private consumption and investment led to surpluses of the current account at the beginning of economic transition. However, high private consumption growth fuelled a rapid rise in imports of consumption goods and resulted in burgeoning current account deficits (up to 7.6% of GDP in 1996) in the later phase of economic reforms. Simultaneously, capital formation slowed sharply and even declined in real terms from 1997. The current account deficits in Hungary can be traced to both imported investment and consumption goods, as reflected by a relatively high negative correlation between these variables between 1991 and 1994. This indicates that increases in imports have been related to the growth of consumption and investment to about the same extent in Hungary. However, the recent period (1995 to 1998) is characterised by an improvement of growth driven by both private consumption and investment and a simultaneous reduction of the current account deficit. This positive development may have several internal and external reasons. Among them, Inotai (1999) argues that the early FDI has already created new export capacities, contributing both to GDP growth and a recent improvement of external balances in Hungary.

In Poland, there is a highly negative correlation of private consumption with the current account, indicating an important share of consumption products in Polish imports. As investment is negatively correlated with the current account too, investment and private consumption seem to have caused increasing current account deficits in Poland recently. Contrary to other CEECs, Slovenia has been characterised by a balanced current account during the entire observation period.

As Calvo et al. (1995) note, the correlation of capital inflows with consumption rather than investment means that CEECs have a greater similarity to Latin American than to Southeast Asian countries. However, this does not necessarily need to cause concern in the CEECs. As Calvo et al. (1995) conclude, private consumption is still relatively low given the level of resources in these countries. Therefore, the recent increase in consumption could reflect a shift towards the equilibrium level of consumption which would be consistent with efficient use of all available resources. However, there is a risk that capital inflows may not be available throughout the whole period of convergence to safeguard the effective allocation of resources and an equilibrium level of consumption in line with countries' resources. Wages and consumption could overshoot the equilibrium level. In both cases, private consumption and real wages may eventually fall, creating social tensions.

Table 1
The current account and selected GDP components in CEECs

	Current account[1]	Real capital formation[2]	Real private consumption[2]	Current account[1]	Real capital formation[2]	Real private consumption[2]
	Czech Republic			Hungary		
1991	1.2	–17.5	–28.5	0.8	–10.4	–5.6
1992	–1.0	8.8	15.5	0.9	–2.6	0.0
1993	0.3	–8.1	2.9	–9.0	2.0	1.9
1994	–0.1	17.3	5.3	–9.4	12.5	0.2
1995	–2.7	21.0	7.0	–5.6	–4.3	–7.1
1996	–7.6	8.7	7.1	–3.8	6.7	–3.2
1997	–6.1	–4.9	1.7	–2.2	9.2	2.6
1998	–1.9	–3.7	–2.3	–4.8	11.4	3.8
Correlation[3]						
1991/1998		–0.245	–0.382		–0.534	–0.240
1991/1994		–0.786	–0.939		–0.840	–0.670
1995/1998		0.107	–0.461		0.586	0.534
	Poland			Slovenia		
1991	–2.6	–4.4	6.3	1.0	–11.5	–11.0
1992	1.1	2.3	2.3	7.4	–12.9	–3.6
1993	–0.7	2.9	5.2	1.5	10.7	13.9
1994	2.5	9.2	4.4	4.2	12.5	3.8
1995	4.6	16.9	3.6	–0.1	17.1	9.2
1996	–2.4	20.6	8.6	0.2	4.2	2.4
1997	–4.2	21.9	7.0	0.2	10.1	3.3
1998	–5.3	14.8	4.5	0.0	13.7	2.4
Correlation[3]						
1991/1998		–0.147	–0.568		–0.541	–0.266
1991/1994		0.927	–0.700		–0.281	–0.125
1995/1998		–0.153	–0.461		–0.900	–0.731

[1] As a share of GDP. [2] Real growth. [3] Correlation of current account (as a share of GDP) and real growth of selected GDP components in indicated periods.

Sources: EBRD; OECD; IMAD Slovenia.

To avoid an increase of the current account deficit, a central bank may choose to intervene against the country's own currency in response to capital inflows, thus increasing its exchange reserves. Under a fixed exchange rate regime, capital inflows, which are converted at a fixed exchange rate to domestic currency, inevitably increase monetary aggregates unless the central bank pursues a sterilisation policy (for example through the sale of government paper).[3] However, sterilisation comes at a cost: when a central bank's domestic liabilities carry a higher interest rate than official exchange reserves do, it

[3] See Oblath (1998) and Durjasz and Kokoszczynski (1998) for a discussion of central bank interventions in Hungary and Poland, respectively.

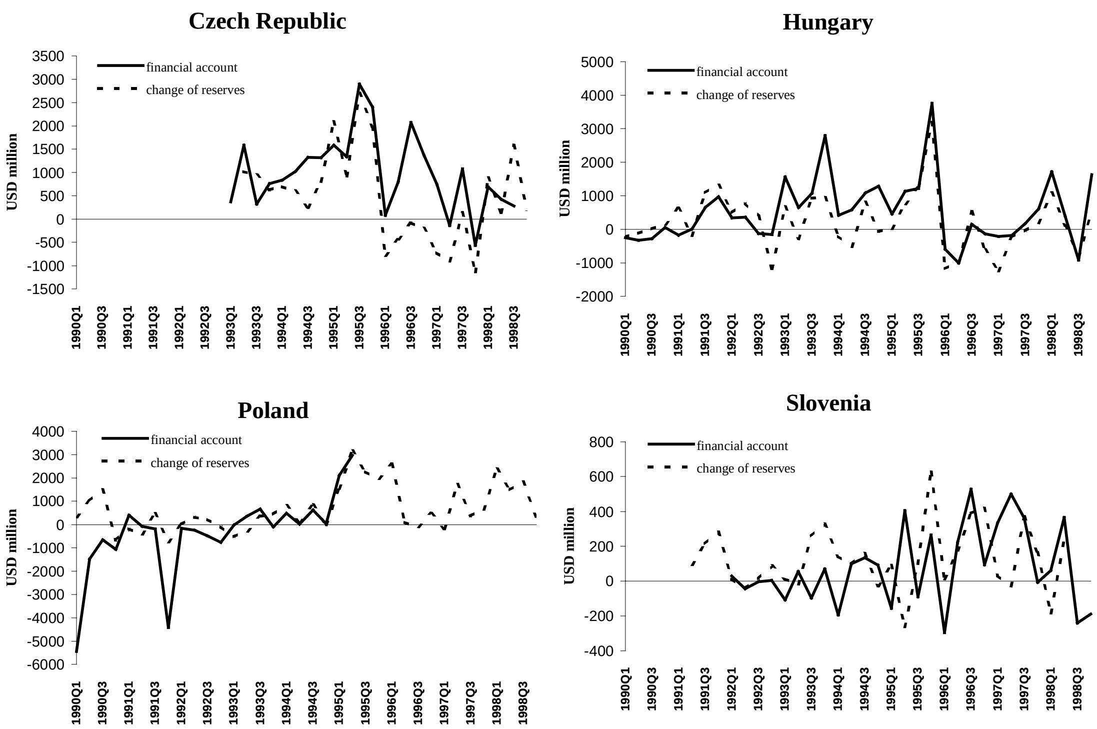
operates at a loss and thus increases the quasi-fiscal deficit. Under conditions of full capital mobility, sterilisation becomes ineffective, as any funds which are withdrawn from the money market by central bank sterilisation operations will quickly be replaced by new capital inflows. The cost of sterilisation will grow. As a consequence, in highly integrated financial markets, central banks have to accept some effect of capital inflows on monetary aggregates, which may cause inflationary pressures.[4]

2.2 Capital flows and exchange reserves in CEECs

Figure 1 shows that, as far as data are available, the growth of official reserves (excluding gold) in the CEECs was largely determined by the surplus on the financial account, whereas the development of the current account did not play an important role (with the possible exception of Slovenia). The Czech Republic, Hungary and Poland posted increasing exchange reserves financed by capital inflows. Declines in exchange reserves, for example in Hungary in 1996 and in the Czech Republic in 1996 and 1997, were likewise largely caused by a decline (Czech Republic) or even a dramatic reversal (Hungary) of capital inflows. The capital flows to Hungary switched from a maximum surplus on the financial account of US$ 3.8 billion in the fourth quarter of 1995 to a deficit of US$ 0.6 billion in the first quarter of 1997, which subsequently increased to US$ 1.0 billion (minimum of the available period). Contrary to the developments in the Czech Republic and Hungary, Poland largely succeeded in avoiding outflows of capital and a resulting decline of exchange reserves. In Slovenia, both capital flows and changes of reserves fluctuated strongly, with the average value relatively close to zero.

Figure 1

Financial account and the development of reserves in CEECs



Source: IMF, *International Financial Statistics (IFS)*.

[4] This effect on monetary aggregates can be avoided if capital inflows are utilised to repay foreign debt.

The relatively close relation between capital flows and exchange reserves is confirmed by the high correlation of these two variables (see Table 2). In Hungary, this correlation was 0.66 between 1990 and 1998. We found the highest correlation ($\rho = 0.80$) for the Czech Republic (1993 to 1998). By contrast, the development of exchange reserves in Slovenia, where capital inflows were relatively smaller, was influenced by other factors (e.g. the current account).

Table 2
Interdependence (correlation matrix) of capital flows in CEECs

		Balance of financial account				Change of exchange reserves			
		CZ	HU	PL	SI	CZ	HU	PL	SI
Czech Republic	ρ	1.000				1.000			
	N	23				23			
Hungary	ρ	0.371	1.000			0.532	1.000		
	N	23	36			23	36		
Poland	ρ	0.433	0.270	1.000		0.322	0.157	1.000	
	N	10	22	22		23	36	36	
Slovenia	ρ	0.167	0.020	0.362	1.000	0.048	0.316	–0.218	1.000
	N	23	28	14	28	21	29	29	29

Note: ρ = Pearson correlation, N = number of observations.
Source: *IFS*.

We also note a common trend in the development of capital flows in central and eastern Europe, which has been described by other authors.[5] This common trend could indicate the relevance of international factors in the explanation of capital flows to central and eastern Europe. The highest inflow of foreign capital to Hungary and the Czech Republic was observed between 1993 and 1995, while both countries experienced a slowdown of capital inflows or even capital outflows between 1996 and 1997. Hungary in particular experienced a high volatility of capital flows in 1998, but for the year as a whole foreign capital inflows were recorded in both countries. Correspondingly, the correlation of capital flows in the Czech Republic and Hungary is relatively high and positive ($\rho = 0.37$); the correlation of the development of foreign reserves is even higher ($\rho = 0.53$).

Table 3
Capital flows and exchange reserves in CEECs
Correlation of financial account and development of exchange reserves in CEECs

	Czech Republic	Hungary	Poland	Slovenia
Observation period	1993Q2–1998Q3	1990Q1–1998Q4	1990Q1–1995Q2	1992Q1–1998Q2
Correlation	0.797	0.663	0.483	0.190

Although Poland experienced episodes of capital outflows at the beginning of the 1990s, on the whole capital flows to Poland are correlated with flows to Hungary to a relatively high degree ($\rho = 0.27$) in the period 1990 to 1995.[6] The development of exchange reserves, which we found to be closely correlated with capital flows,[7] indicates that capital flows to Poland also continued in the more recent

5 Calvo et al. (1995); UNCTAD, *World Investment Report 1999*.

6 In the IMF's *International Financial Statistics*, quarterly balance of payments data are available only up to 1995.

7 A close relation between capital flows and the development of exchange reserves is assumed in some other studies, too: Calvo et al. (1993) use changes in exchange reserves as an approximation of capital flows to selected Latin American countries.

Table 4

Development of components of monetary aggregates in CEECs

	Monetary base (MB)		Monetary authorities: NFA		Monetary authorities: NDA	M2		Banking system: NFA*	Banking system: NDA	Nom. GDP	GDP def.
	local curr. (mln)	% change	local curr. (mln)	As a % of MB	Local curr. (mln)	local curr. (mln)	% change	local curr. (mln)	local curr. (mln)	% change	
Czech Republic											
1991	–	–	–	–	–	–	–	–	–	29.4	46.2
1992	–	–	–	–	–	–	–	–	–	13.0	16.8
1993	166	–	148	89.0	–57	697	–	194	503	18.6	17.9
1994	223	34.4	204	91.6	17	840	20.4	233	607	14.4	10.9
1995	343	53.6	400	116.7	–59	1086	29.3	344	741	20.2	9.8
1996	344	0.5	367	106.7	–34	1156	6.4	310	845	13.8	9.6
1997	345	0.1	367	106.4	–25	1175	1.7	429	746	6.9	6.5
1998	422	22.5	403	95.4	19	1214	3.4	510	704	8.4	11.0
Hungary											
1991	799	52.3	237	29.7	311	1183	29.4	279	904	19.6	25.4
1992	888	11.1	274	30.8	391	1506	27.3	317	1189	17.8	21.6
1993	1019	14.8	549	53.9	189	1759	16.8	593	1166	20.6	21.3
1994	1169	14.7	636	54.4	237	1988	13.0	615	1373	23.0	19.5
1995	1516	29.7	1576	103.9	–270	2355	18.4	1508	846	28.6	25.5
1996	–	–	–	–	–	2854	21.2	–	–	22.8	21.2
1997	–	–	–	–	–	3507	22.9	–	–	23.9	18.5
1998	–	–	–	–	–	–	–	–	–	19.2	13.4
Poland											
1991	10943	28.2	3709	33.9	4492	26102	37.0	7791	18311	44.4	55.3
1992	14860	35.8	5951	40.0	4987	41108	57.5	13405	27703	42.1	38.5
1993	15993	7.6	7702	48.2	3468	55924	36.0	17212	38712	35.5	30.5
1994	19615	22.6	11340	57.8	6	77302	38.2	26448	50854	35.1	28.4
1995	28441	45.0	36636	128.8	–9989	104352	35.0	49184	55169	45.6	27.9
1996	34262	20.5	51789	151.2	–18944	136517	30.8	61524	74993	25.8	18.7
1997	45919	34.0	72284	157.4	–32798	176391	29.2	82808	93583	21.8	14.0
1998	53656	16.9	95610	178.2	–49159	220765	25.2	96300	124465	17.4	12.0
Slovenia											
1991	16	–	7	40.8	9	120	–	47	73	77.6	94.9
1992	37	133.1	71	190.7	–34	267	123.0	158	109	191.3	208.2
1993	51	38.2	103	199.8	–54	432	62.2	152	281	41.0	37.1
1994	81	56.9	189	235.0	–111	626	44.7	321	305	29.1	22.6
1995	101	25.2	250	248.4	–151	812	29.8	365	447	19.9	15.2
1996	117	15.6	330	282.8	–214	1001	23.3	488	513	15.0	11.1
1997	143	23.0	559	390.1	–416	1235	23.3	669	566	13.8	8.8
1998	172	19.7	594	346.1	–423	1476	19.5	702	774	11.6	7.3

Note: Monetary based reserve money. NFA = net foreign assets = foreign assets – foreign liabilities; NDA = net domestic assets = monetary base – net foreign assets; M2 = money + quasi money; GDP def. = GDP deflator.

* Excluding long-term foreign liabilities.

Sources: *IFS*; National Bank of Hungary.

period. Capital flows to Slovenia developed relatively independently of those in other CEECs, as both indicators show (Table 3).

2.3 Capital flows and monetary aggregates

In the previous section, we saw that capital flows fuelled sizeable increases in exchange reserves in most CEECs. The aim of this section is to investigate to what degree this capital inflow-driven build-up of exchange reserves had an impact on the development of monetary aggregates, in order to assess the inflationary potential arising from capital inflows.

Calvo et al. (1995) argue against sterilisation activities by CEE central banks in the early phase of transition (until 1993), because they ascribe increasing capital flows in this phase to rising money demand. Therefore, capital flows would not pose a danger for price stability. The development of inflation rates until 1995 lends support to this view. Although M2 was often growing more quickly than nominal GDP in the CEECs during this period, inflation rates were declining (inflationary shocks such as the devaluation in Hungary in 1995 are of course exceptions).

In about 1993, CEE central banks started to sterilise inflows, as documented by a sharp increase in the share of net foreign assets in the monetary base, as central banks were trying to reduce net domestic assets in response to quickly growing net foreign assets. Table 4 provides an overview of the extent of sterilisation operations in the CEECs: according to this table, the increase in net foreign assets was matched most closely by a decrease in net domestic assets in Slovenia. In Hungary and Poland, increases in net foreign assets were largely offset by declining net domestic assets while in the Czech Republic the degree of sterilisation appears to be the lowest. However, one should be aware of the problems involved in this simple comparison: As Oblath (1998, p. 197) points out, we are dealing with ex post information. Thus, we cannot tell to what extent the sterilised funds would have contributed to an increase in the current account deficit and/or the monetary base. In addition, the reaction of capital inflows in response to sterilisation measures is not captured.

The extent of sterilisation is also an indicator for the degree of integration into international financial markets. As stated above, under conditions of full capital mobility, sterilisation is ineffective. Thus, sterilisation operations would make little sense. One way to assess the effectiveness of sterilisation is to estimate offset coefficients. The change in the central bank’s net foreign assets is explained by a change in net domestic assets and other variables. A coefficient of –1 for net domestic assets would imply the total ineffectiveness of sterilisation (or full integration into financial markets), as any decrease in net domestic assets would be met by an increase of equal size in net foreign assets. Buch et al. (1999) present a good overview of attempts to estimate offset coefficients in CEECs. They find that, with the possible exception of Slovenia, which was not covered in their study, CEECs exhibit a rather high degree of financial integration. Thus, the possibility of finding evidence of a relationship between capital inflows and inflation in CEECs should not be ruled out ex ante, as sterilisation policies seem not to have succeeded in fully insulating monetary aggregates from capital inflows.

3. Capital flows and inflation: a case study of Hungary

Because of a lack of data on the other countries covered by this study, we are able to explore these relationships in greater detail only for Hungary. This section discusses bivariate and multivariate relations between various types of capital flows and selected monetary variables in Hungary between 1992 (FDI) or 1994 (portfolio investment) and 1999.

Table 5 shows the result of Granger causality tests applied to capital flows (foreign direct investment and portfolio investment in Hungary) and selected monetary variables, including various price indices, real and nominal effective exchange rate indices, and various interest rates. We can see that the motives of direct investors are substantially different to those of portfolio investors. Direct investors are motivated mainly by real wages and exchange rates, while portfolio investors are attracted by the interest rate level. Various price indices are the only variables which exhibit a statistically significant relationship with both types of investment. Simultaneously, prices also seem to be influenced by both types of capital flows. Thus, the relation between prices and capital flows could be mutual. Capital flows do not seem to have any other significant effects on the Hungarian economy. These results are largely similar to those presented by Halpern (1996).

Table 5
Granger causality test between capital flows and selected variables

	H0: Selected variables do not Granger cause capital flows				H0: Capital flows do not Granger cause selected variables			
	FDI	FDI	PI	PI	FDI	FDI	PI	PI
Number of lags	2	4	2	4	2	4	2	4
Number of observations	28	28	24	24	28	28	24	24
Real wages	*0.79*	**5.66**	*0.07*	*0.25*	*0.18*	*0.38*	*0.10*	*1.16*
CPI, beverages	*0.08*	*0.48*	**5.46**	2.69	**8.84**	**5.99**	*1.21*	*0.98*
CPI, services	*0.49*	2.80	**3.59**	*2.30*	**4.88**	*1.85*	*1.06*	*0.78*
CPI, energy	**6.28**	**3.23**	*1.78*	*1.10*	*0.51*	*0.69*	3.14	*1.24*
CPI, foodstuffs	*2.13*	**3.74**	*0.41*	*0.17*	*0.02*	*0.55*	*1.19*	*1.09*
CPI, total	*1.80*	2.36	2.81	*1.40*	*1.85*	*0.37*	**3.55**	*2.12*
Real effective exch. rate	**6.60**	**3.12**	*0.05*	*0.28*	*0.33*	*0.57*	*0.87*	*0.30*
Nom. effective exch. rate	**8.00**	**4.63**	*0.34*	*0.36*	*0.46*	*1.79*	*1.26*	*0.44*
Lending rate	*0.95*	*0.63*	**9.19**	3.38	*1.47*	*0.60*	*0.53*	2.91
Deposit rate	*0.13*	*0.16*	**5.76**	3.10	*0.41*	*0.20*	*0.88*	*0.73*
Treasury bills	*0.04*	*0.18*	**4.50**	2.72	*0.87*	*0.37*	*0.41*	*1.24*
Discount rate	*0.34*	*1.42*	**7.05**	2.85	*0.66*	*0.47*	*1.92*	*0.12*

Note: FDI = foreign direct investment; PI = portfolio investment; italics = not significant; bold print = significant at 5% level; normal print = significant at 10% level.

However, Granger causality tests do not provide information on the character of the relationship between selected variables. Furthermore, omitted variables may bias the test results. Therefore, we specified a vector autoregression (VAR) model of inflation in Hungary. The endogenous variables include the consumer price index (CPI), interest rates on treasury bills (TBR), and the nominal effective exchange rate (NEER). Treasury bill rates are highly correlated with lending rates and other interest rates, and can be taken as a proxy for the general level of interest rates in Hungary.

Furthermore, we included two exogenous variables, direct and portfolio investment (FDI and PI, respectively) converted to Hungarian forints. All variables are first differences, as indicated by D(.) in Table 6.

This model explains about 60% of the variance of the quarterly changes in consumer prices and about one third of the changes in interest rates and the exchange rate. As estimated impulse-response functions reveal, interest rate growth and exchange rate depreciation (displayed as a downward movement of the exchange rate index) increase inflation for one to two years. Depreciation and inflation cause the interest level to rise with a lag of about two quarters, which falls to zero after one year. The nominal effective exchange rate reacts most rapidly to a change in the other endogenous variables. An inflation shock causes a depreciation with a lag of two or three quarters, while higher interest rates already cause appreciation after one quarter. These effects diminish within one year.

Table 6
VAR model of inflation in Hungary, 1992Q1 – 1999Q1

Endogenous variables	D(CPI)	D(TBR)	D(NEER)
D(CPI(–1))	0.476582	–0.200883	–0.285508
	(0.15251)	(0.25815)	(0.28163)
	(3.12482)	(–0.77818)	(–1.01376)
D(CPI(–2))	–0.416958	0.187135	–0.162131
	(0.15264)	(0.25835)	(0.28185)
	(–2.73172)	(0.72435)	(–0.57523)
D(TBR(–1))	0.026429	0.560851	–0.411247
	(0.12961)	(0.21937)	(0.23933)
	(0.20392)	(2.55665)	(–1.71834)
D(TBR(–2))	–0.014794	–0.055568	–0.102888
	(0.13908)	(0.23541)	(0.25682)
	(–0.10637)	(–0.23605)	(–0.40062)
D(NEER(–1))	–0.083702	–0.068417	0.096950
	(0.11932)	(0.20195)	(0.22033)
	(–0.70152)	(–0.33878)	(0.44003)
D(NEER(–2))	–0.265803	0.101204	–0.014731
	(0.10562)	(0.17877)	(0.19504)
	(–2.51661)	(0.56611)	(–0.07553)
Exogenous variables			
US$(–1)*FDI(–1)	9.87E–06	–6.08E–06	6.69E–06
	(3.6E–06)	(6.0E–06)	(6.6E–06)
	(2.77474)	(–1.00968)	(1.01891)
US$(–1)*PI (–1)	–1.02E–05	–1.08E–06	3.90E–06
	(4.3E–06)	(7.3E–06)	(7.9E–06)
	(–2.37475)	(–0.14826)	(0.49141)
Constant	2.706011	0.339926	–1.750549
	(0.95027)	(1.60843)	(1.75476)
	(2.84761)	(0.21134)	(–0.99760)
R-squared	0.621711	0.349859	0.309447
Adj. R-squared	0.470395	0.089802	0.033225
F-statistic	4.108703	1.345319	1.120285
Log likelihood	–50.74219	–66.00380	–68.52901
Akaike AIC	4.120151	5.172676	5.346828
Schwarz SC	4.544484	5.597009	5.771161

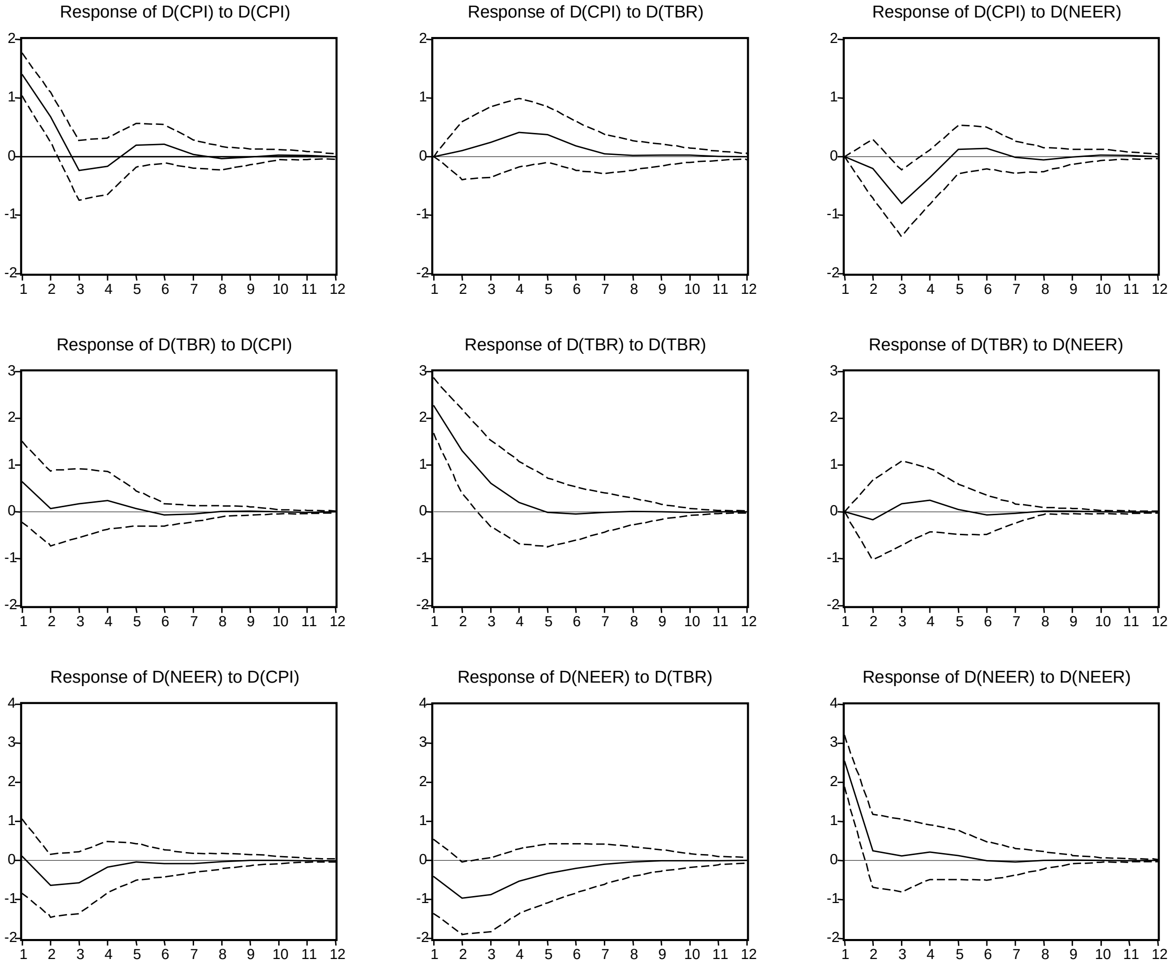
Note: Standard errors and t-statistics in parentheses.
Source: *IFS*.

In this system, the coefficient of foreign direct investment is statistically significant and positive in the first equation while portfolio investment exhibits a statistically significant negative relation with the inflation rate.

However, the relationship between portfolio investment and the inflation rate is not robust: when the interest rate variable is changed, the t-value of the coefficient of portfolio investment is no longer significant. Both types of investment seem to reduce the interest level and support an appreciation of the nominal effective exchange rate in Hungary. Other model specifications, which included the aggregated financial account, performed substantially worse. There is no significant relationship between the financial account and the inflation rate.

Figure 2
VAR impulses to indicators' shocks in Hungary

Response to one SD innovation ± 2 SE



These effects are, incidentally, in accordance with the experiences of other countries (see Christoffersen and Wescott (1999) and Calvo et al. (1993)).

4. Impact of capital inflows on financial stability

4.1 Theoretical considerations

Capital flows can pose a threat to financial stability via two main channels: first, capital flows may cause an excessive real appreciation of the exchange rate and, second, they may produce a currency and maturity mismatch of assets and liabilities in the financial sector. While the first channel is relevant for both flexible and fixed exchange rate systems the second is decidedly more relevant for fixed exchange rate systems. Such a system encourages borrowing at lower interest rates in foreign currency as long as the exchange rate target of the central bank remains credible, and this may result in high open foreign exchange positions of banks (i.e. a currency mismatch of assets and liabilities) and firms. Even when capital inflows take the form of purchases of domestic currency-denominated assets by foreigners rather than borrowing in foreign currency capital, inflows pose additional risks for financial stability. As explained above, under conditions of full capital mobility, the central bank has no control over the monetary base under fixed exchange rates. If the monetary base increases because of capital inflows, broader monetary aggregates will expand more than the amount of initial inflows because of the money multiplier. Thus, there will be a rise in the ratio of M2/ official reserves, which implies that the gap between liquid domestic assets (which could be converted into foreign currency-denominated assets) and the stock of foreign exchange available for meeting this demand grows. Although this problem can be mitigated through the use of higher minimum reserves, it cannot be avoided altogether.

Under conditions of less than full capital mobility, when sterilisation is partly effective, there are still some unwanted side effects. Beside the fiscal costs of sterilisation, the structure of capital inflows is likely to change in response to sterilisation operations. Montiel and Reinhart (1999) find evidence for a change in the composition of capital inflows in favour of short-term and portfolio flows as a result of sterilisation operations. At fixed exchange rates, capital inflows also tend to increase maturity mismatches in the banking sector, as foreigners' deposits with domestic banks will often have shorter maturities than the credits which are funded by the deposits.

In the light of the preceding discussion, a floating exchange rate system seams a preferable solution. It certainly has the big advantage that it does not encourage quasi-arbitrage between domestic and foreign interest rates, which would increase the fragility of the financial system. However, a floating regime is not entirely free from complications either. White (1999) gives a good overview of challenges for central banks which arise from the adoption of a floating exchange rate/direct inflation targeting framework. For transition economies, the issue of exchange rate overshooting seems to be of particular relevance. The expectation of large FDI inflows as a result of privatisation projects might also attract short-term inflows, which could lead to an overvaluation of the exchange rate. Beside the negative impact of an exchange rate misalignment on the real sector, strong expectations of exchange rate appreciation could induce banks and businesses to borrow excessively in foreign currency.

4.2 Development of economic and financial indicators

Given that we defined financial stability as the absence of financial crises, we analyse variables which are associated in the literature with financial crises. Kaminsky et al. (1998), who conducted extensive studies of a large number of balance of payments crises, identify the real exchange rate, banking crises, exports, stock prices, M2/reserves and output as the most reliable leading indicators of balance of payments crises. The real exchange rate, stock prices, the M2 multiplier, output and exports are mentioned by Reinhart (1999) as the most successful "predictors" of banking crises. As there are neither adequate time series of these indicators nor enough observations of crises available in CEECs, the empirical testing of the relevance of these indicators for transition countries is impossible at present. Thus, we have to stick to the presentation of "stylised facts" of the development of a set of indicators of financial vulnerability which is based on the findings of Kaminsky et al. (1998) and Reinhart (1999). We divided our set of financial indicators into two groups, monetary and real variables. The first group of variables should be expected to reflect credit booms and asset bubbles fuelled by the strong money supply growth resulting from capital inflows. The second group tends to mirror symptoms of the excessive real appreciation of the exchange rate.

4.2.1 Monetary variables: M2/reserves, short-term debt/reserves, stock prices

When the reforms began, the Czech Republic and Poland had to cope with very low levels of international reserves, resulting in high M2/reserves ratios. In about 1993, CEE central banks started to sterilise capital inflows, resulting in a sharp fall in this ratio until 1995. By then, international reserves had accumulated to a level deemed sufficient and – as stated before – the management of continuing capital inflows from the viewpoint of monetary and financial stability became an important issue in the accession countries. Apart from Slovenia,[8] all countries had started to follow a strategy of exchange rate targeting by that time, and steps to liberalise the capital account had been taken, with the

[8] Slovenia pursues a policy of monetary targeting but pays strong attention to exchange rate developments. Thus, in practice this policy comes close to a strategy of exchange rate targeting.

Czech Republic leading in this respect. In the next two years, this ratio again worsened markedly in Hungary and the Czech Republic, albeit starting from a low level. Although this indicator did not seem to have reached an alarming level by 1997,[9] the Czech Republic experienced a currency crisis. Thus, a capital inflow-driven credit boom does not seem to be the main cause of the crisis in the Czech Republic. Comparing a measure of liquid domestic assets such as M2 with the amount of foreign assets available in the economy to satisfy the demand for domestic assets if there is a run on the currency may yield insights into the severity of an exchange rate correction in the event of a loss of credibility. This could explain why the fall of the Czech koruna was fairly limited and why the currency crisis did not develop into a twin crisis.[10]

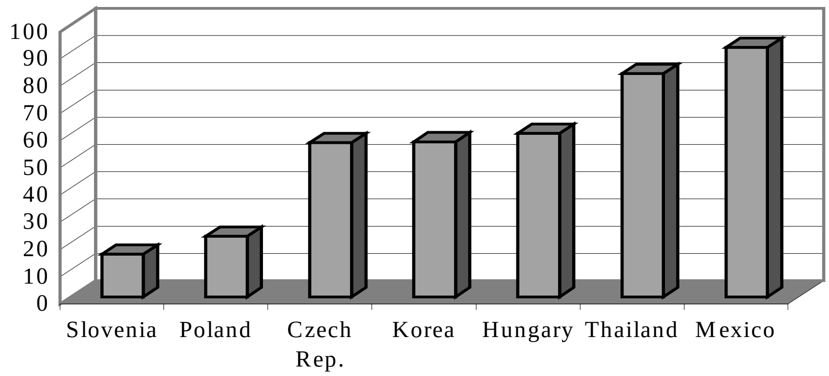
Table 7
M2/reserves

	Czech Republic	Hungary	Poland	Slovenia
1993	6.20	2.59	6.12	4.16
1994	4.98	2.65	5.26	3.30
1995	2.79	1.40	2.82	3.54
1996	3.30	1.78	2.64	3.08
1997	3.60	2.05	2.43	2.20
1998	3.38	1.97	2.30	2.51

Note: Since 1998, Hungary has not published figures for M2; the 1998 figure is based on the ratio of M2/M3 in 1997.

Sources: WIIW monthly reports; National Bank of Hungary.

Figure 3
Ratio of outstanding short-term debt to international reserves
In per cent, at end-1998



Sources: BIS; IMF *International Financial Statistics*.

While Reinhart's (1999) set of financial indicators includes the M2 multiplier, we include the ratio of short-term debt/reserves instead. Except for Poland, which experienced a noticeable growth trend of the M2 multiplier in the 1990s, in our view the development of this indicator does not yield many

9 Before the onset of the crisis, Korea's and Mexico's M2/reserves ratios reached levels of 6 to 7.

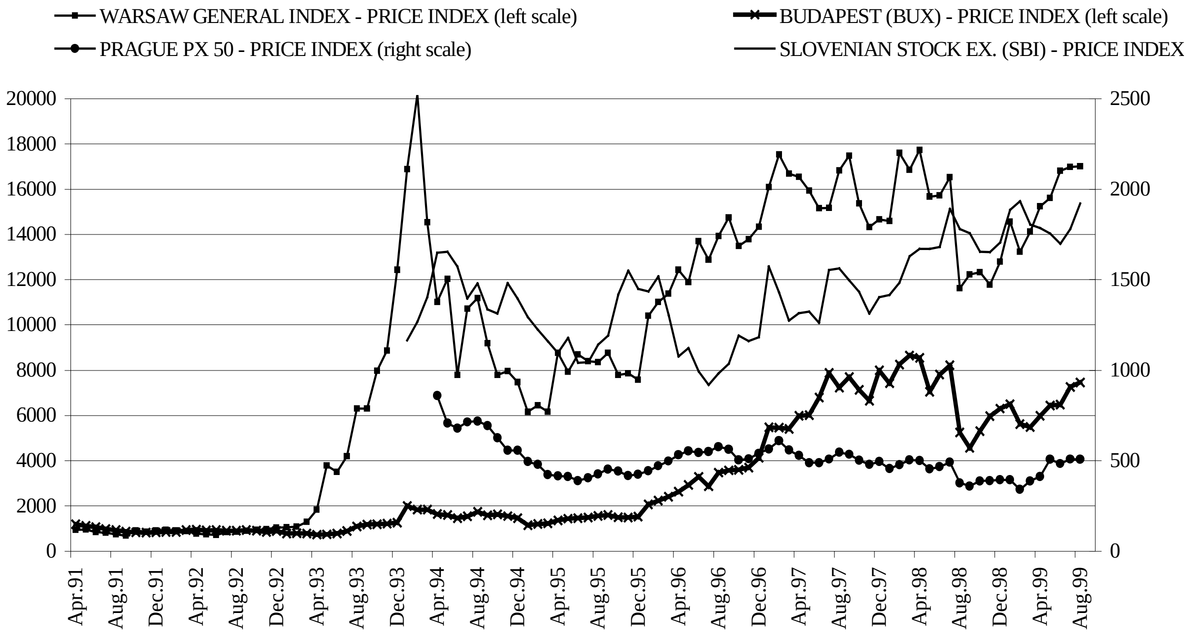
10 Obviously, the Czech banking system has problems but they are a consequence of poor lending practices rather than exchange rate losses.

insights for our purposes. As Reinhart's (1999) investigations focus on the *evolution* of selected variables, the ratio of short term debt/reserves might not fit the author's concept. However high *levels* of short term debt/reserves are associated with several recent crisis experiences (Thailand, Korea, Mexico, Russia). Thus, the level of this ratio might be relevant for the analysis of the vulnerability of the financial system. Generally, low levels of this ratio seem to reflect the limited vulnerability of accession countries to sudden outflows of short-term funds. It also confirms the view that CEE banks have not borrowed aggressively abroad to fund domestic credits.

Source: Datastream.

Figure 4

Regional stock indices



Stock prices fell significantly before the Czech currency crisis, but even sharper falls had occurred in 1994 and after the crises in Asia and Russia. The bubble observed in Poland and the Czech Republic in 1994 was a result of the underdeveloped state of the stock market and had little effect on the banking sector and the economy as a whole. Although the market capitalisation and the liquidity of accession countries' equity markets have improved markedly, their role for the economy as a whole is probably still fairly unimportant. However, falls in CEE stock indices as a result of poor profitability of banks (which are heavily weighted in the indices) and large corporations might signal problems for the banking sector.

4.2.2 Real variables: real exchange rate, export volumes, output

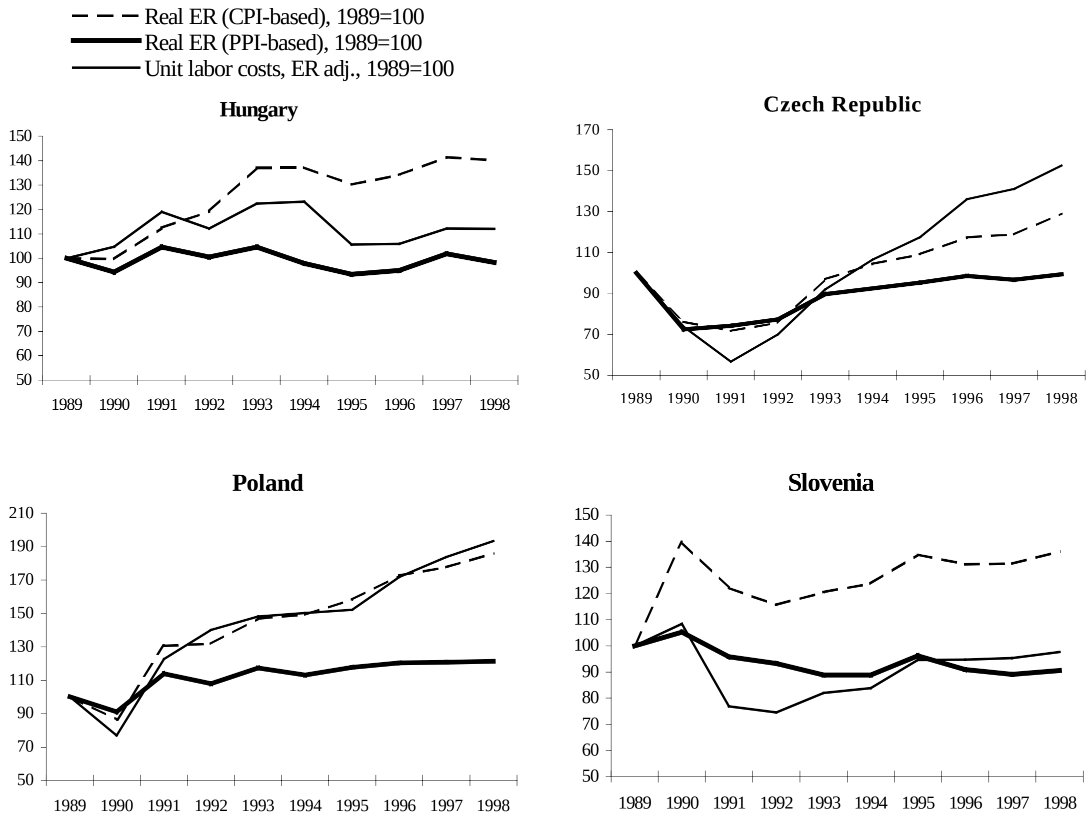
Empirical studies by Halpern and Wyplosz (1997) and Krajnyak and Zettelmeyer (1997) that attempt to estimate equilibrium dollar wages for transition countries point to significant undervaluations of exchange rates[11] at the beginning of transformation. In the meantime, all regional currencies have appreciated significantly in real terms (on the basis of consumer prices), which raises the question of whether real appreciation might have gone too far. Things are complicated by the fact that equilibrium exchange rates are likely to appreciate during the transformation process. We would like to repeat some of the arguments put forward by Halpern and Wyplosz (1997) stating why this should be the

[11] Slovenia is an exception in this respect. However, Halpern and Wyplosz (1997) calculate equilibrium wages for Slovenia on the basis of data for former Yugoslavia, which is clearly problematic.

case: first, when formerly highly inefficient economies begin to respond to market forces, large gains in productivity can be expected. In parallel, a reduction of the sizeable industrial and agricultural sectors will take place, while the service sector (banking and finance, marketing, etc.) should grow strongly. When incomes begin to grow, demand for non-tradables rises, resulting in real appreciation. Second, if productivity gains in the tradables sector outperform productivity gains in the non-tradables sector, a real appreciation takes place according to the Balassa-Samuelson effect. Although this might appear contradictory to the previous argument, these effects are not mutually exclusive and may occur together or sequentially. Third, in planned economies natural resource prices and prices for public utilities were commonly set below market prices, leading to low non-tradables prices. These prices were raised gradually, resulting in real appreciation. Finally, improvements in product quality and better marketing should contribute to an improvement in the terms of trade.

Figure 5

Real exchange rates and unit labour costs

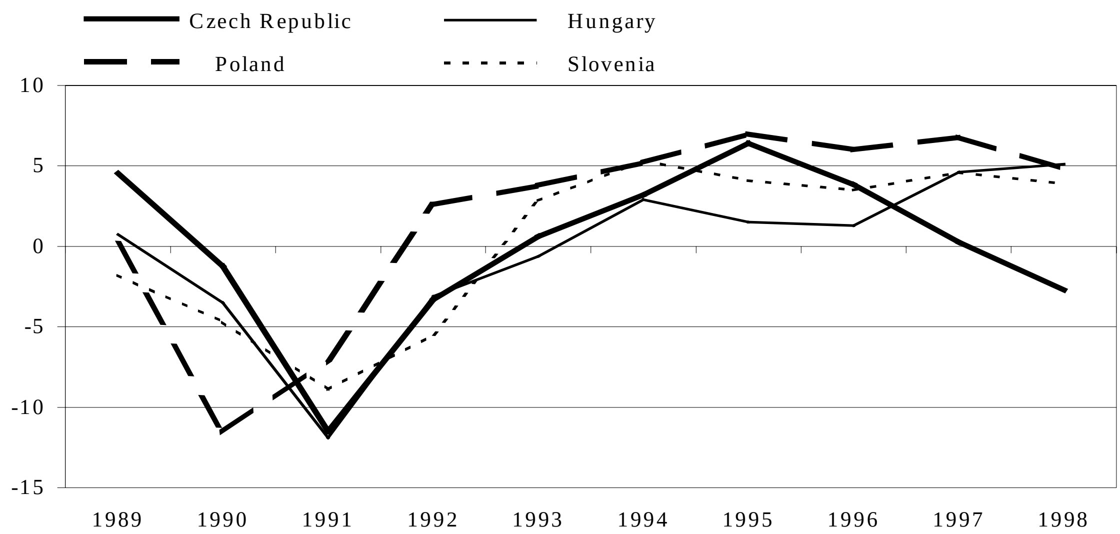


Source: Havlik (1999).

All countries in our sample except for Poland show a fairly uniform appreciation of the real exchange rate on a CPI basis of about 30% to 40% between 1989 and 1998. In the case of Poland, the appreciation amounted to 85%. Consistent with the arguments presented above, the real appreciation on the basis of the CPI (which has a much higher content of non-tradables) is significantly more pronounced than the appreciation on a PPI basis. In 1998, the Czech Republic and Hungary approached the PPI-based real exchange rate levels of 1989, while Slovenia continued to remain below the 1989 level. Poland proved to be an exception once more, with a real appreciation of more than 20%. As real exchange rates on a PPI basis (which represent the tradables sector better than the exchange rates on a CPI basis do) did not appreciate much against the currency of the most important trading partner, the European Union, there seems to be little danger of an exchange rate misalignment.

The analysis of unit labour costs yields a more mixed picture, however. Slovenia and Hungary experienced only small rises in exchange rate adjusted (ECU-based) unit labour costs of 6.8% and 12.2% respectively, whereas unit labour costs in Poland and the Czech Republic shot up by 108% and 56% respectively. Several observations seem to confirm the high relevance of unit labour costs for explaining trade and current account deficits: first, Slovenia, which experienced the smallest rise in exchange rate adjusted unit labour costs, has traditionally had a balanced current account or even surpluses. Second, episodes of very large current account deficits (Hungary 1994, Czech Republic in 1996) occurred after sharp rises in exchange rate adjusted unit labour costs. At first glance, the massive rise in Polish exchange rate adjusted unit labour costs, which did not cause severe macroeconomic imbalances up to 1998, may appear difficult to explain. However, by far the largest rise in unit labour costs occurred in 1991, which caused a marked erosion of the previous trade balance surplus. Nevertheless, the current account remained in check as a result of the debt relief granted to Poland. This debt relief caused a rise in the equilibrium exchange rate, as it reduced the need to achieve surpluses in the trade balance in order to service its foreign debt. Second, trade in US dollars, and in particular trade with CIS states, is more relevant for Poland than for the other countries covered in this paper. Approximately 16% of (classified) Polish exports went to CIS countries before the Russian crisis.[12] As the Russian rouble's real appreciation before the crisis was in excess of the real appreciation of the Polish zloty, Poland's trade-weighted (effective) exchange rate appreciated less than the ECU-based rate before the Russian crisis. As a result, until the outbreak of the Russian crisis there were no visible symptoms of an overvalued exchange rate in Poland. However, if one perceives the loss of the CIS export markets for Poland as permanent (at least for the medium term), the possibility exists that the zloty became overvalued at the end of 1998.

Figure 6
Real GDP growth
Annual percentage changes

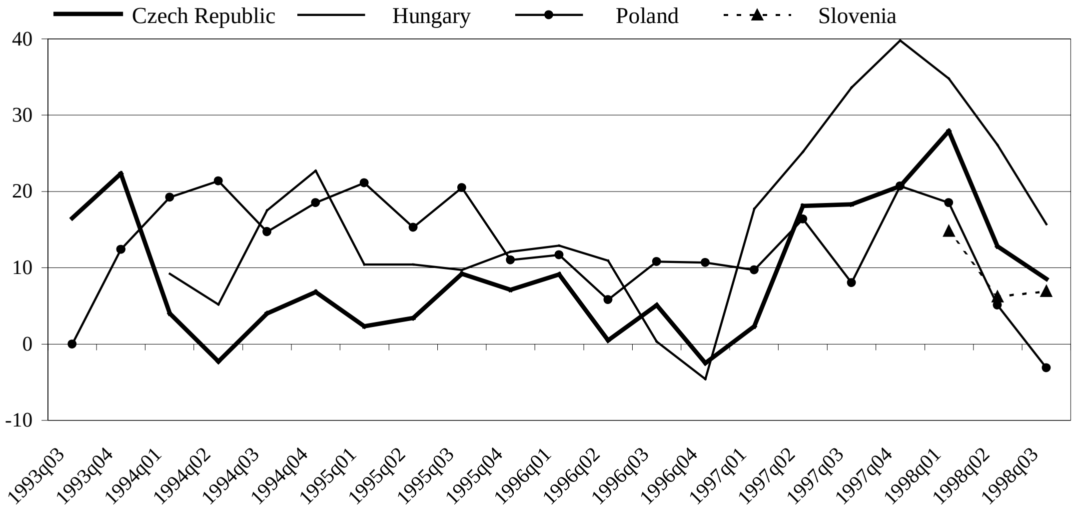


Source: WIIW monthly reports.

Output and export dynamics also support the view that no exchange rate misalignment occurred in Poland until 1998, while in the Czech case symptoms appeared which might point to a misalignment of the Czech koruna under short-run considerations. Before the Czech koruna's devaluation in 1997, Czech exports markedly lagged Polish exports, whereas the situation reversed after the devaluation of the Czech currency. GDP growth rates paint the same picture: continued high GDP growth rates in Poland contrasted with slowing growth rates and rising current account deficits in the Czech Republic before the Czech currency crisis.

12 Poland's surplus in unclassified trade was also reduced significantly by the Russian crisis.

Figure 7
Export volume growth
Annual percentage changes



Source: Eurostat.

5. Implications for monetary and financial stability

When drawing conclusions for the conduct of monetary policy from our results, one must take into account the limits of the study, in particular the shortness of the time series and possible effects of structural changes in the transition economies covered. Bearing these caveats in mind, we consider the results of our VAR model for Hungary to be fairly encouraging. As mentioned before, the variance of the first differences of the CPI can be attributed to a large degree by the explanatory variables. There seems to be a fairly robust relationship between the development of the nominal exchange rate and the inflation rate, whereas the statistical link between nominal interest rates and inflation seems to be much weaker. Thus, this result provides support for the strategy of exchange rate targeting Hungary pursued throughout the sample period.[13] As interest rates are set in accordance with the exchange rate target and thus play a rather passive role, one would expect the exchange rate development to have a stronger impact on inflation than interest rates would. However, throughout the sample period Hungary had restrictions on capital movements in place which provided the National Bank of Hungary with some leeway in its interest rate policy notwithstanding the exchange rate target. As a result, ex ante, the possibility of a relationship between interest rates and the inflation rate might be considered. However, it is not certain that a statistically significant relationship between exchange rate variables and inflation can be found, as the exchange rate's role as a nominal anchor might be disturbed, for example by the process of price liberalisation. Our findings of a poor (statistical) link between interest rates and inflation on the one hand, and a fairly good linkage between the exchange rate and inflation on the other hand are in accordance with Christofferson and Wescott's (1999) results for Poland.

Our results suggest that, while Hungary sterilised capital inflows to a relatively high degree, it did not manage to prevent capital flows from having a certain effect on the inflation rate. The VAR model as well as the Granger causality test provide evidence for an impact of FDI on the inflation rate. Although the negative relation between portfolio inflows and the change in consumer prices would indicate a dampening effect of portfolio inflows on the inflation rate, this result should be treated with

[13] Since 1995, Hungary has pursued a "crawling peg regime". Before the introduction of this system, Hungary had applied a policy of devaluations on an irregular basis.

some scepticism. First, it is contrary to theoretical expectations and, second, the relation is statistically not robust. As FDI inflows appear to be related to the inflation rate although this is not the case for the financial account as a whole, one may conclude that FDI causes some demand-driven inflation, whereas the danger of a credit boom as a result of a large total inflow amount channelled through the banking system seems to be rather limited. This would suggest that growth in monetary aggregates is a weak link between capital inflows and inflation.

The levels and dynamics of financial indicators presented in this paper point to a relatively moderate vulnerability of the CEECs to financial crises at present. Few signs of a worsening of the indicators which seem to be caused by increasing financial integration could be detected. This overall positive assessment is supported by the relatively limited impact of the Russian crisis on the more advanced CEECs. On the contrary, there is no definitive answer as to how far the indicators applied in this study were able to "predict" the balance of payments crises in Hungary in 1994/95 and in the Czech Republic in 1997. However, it seems fair to conclude that the development of exchange rate adjusted unit labour costs was a relevant indicator in both cases. While the Hungarian crisis occurred under conditions of limited integration into international financial markets, the question of to what degree the advanced state of integration of the Czech Republic contributed to the Czech crisis cannot be fully answered. Among the indicators which we presented in this paper, the "real variables" reflect the problems in the Czech economy better than the "monetary variables". If improper intermediation of capital inflows were the main factor behind the crisis, the "monetary indicators" should look worse. Thus, we would draw the conclusion that excessive real appreciation (measured by exchange rate adjusted unit labour costs) in the run-up to the crisis is more relevant for explaining the Czech currency crisis. However, the question of whether capital inflows contributed to the worsening of exchange rate adjusted unit labour costs in the run-up to the crisis remains open.

Bibliography

Buch, Claudia M, Ralph P Heinrich and Christian Pierdzioch (1999): "Foreign Capital and Economic Transformation: Risks and Benefits of Free Capital Flows". Kieler Studien 295.

Christoffersen, Peter F and Robert F Wescott (1999): "Is Poland Ready for Inflation Targeting?" *Working Paper*, No. 99/41, International Monetary Fund, Washington D.C.

Calvo, Guillermo A, Ratna Sahay and Carlos A Végh (1995): "Capital Flows in Central and Eastern Europe: Evidence and Policy Options". *Working Paper*, No. 95/57, International Monetary Fund, Washington D.C.

Calvo, Guillermo A, Leonardo Leiderman and Carmen M Reinhart (1993): "Capital Inflows and Real Exchange Rate Appreciation in Latin America". *IMF Staff Papers*, No. 40 (1), pp. 108-51.

Durjasz, Pawel and Ryszard Kokoszczynski (1998): "Financial Inflows to Poland, 1990-96". *Empirica*, 25 (2).

Halpern, László (1996): "Real Exchange Rate and Exchange Rate Policy in Hungary". *Economics of Transition*, 4 (1), pp. 211-28.

Halpern, László and Charles Wyplosz (1997): "Equilibrium Exchange Rates in Transition Economies". *IMF Staff Papers*, 44 (4), pp. 430-61.

Havlik, Peter (1999): "The Transition Countries in 1999: A Further Weakening of Growth and Some Hopes for Later Recovery". The Vienna Institute for Comparative Economic Studies (WIIW) *Research Report*, No. 257, pp. 1-42, June.

Inotai, Andras (1999): "Die beitrittswilligen Staaten auf dem Weg in die Europäische Union - Ungarn auf dem Vormarsch", in BMwA: *Österreichs Außenwirtschaft*, 1998/1999, pp. 205-16.

Kaminsky, Graciela, Saul Lizondo and Carmen M Reinhart (1998): "Leading Indicators of Currency Crises". *IMF Staff Papers*, 45 (1), pp. 1-48.

Kaminsky, Graciela and Carmen M Reinhart (1999): "The Twin Crises: The Causes of Banking and Balance-of-Payments Problems". *American Economic Review*, 89(3), pp. 473-500, June.

Krajnyak, Kornelia, and Jeromin Zettelmeyer (1997): "Competitiveness in Transition Economies: What Scope for Real Appreciation?" *Working Paper*, WP/97/149. International Monetary Fund, Washington D.C.

Montiel, Peter and Carmen M Reinhart (1999): "Do Capital Controls and Macroeconomic Policies Influence the Volume and Composition of Capital Flows? Evidence from the 1990s". *Journal of International Money and Finance*, forthcoming.

Oblath, Gabor (1998). "Capital Inflows to Hungary in 1995-96 and the Accompanying Policy Responses". *Empirica*, 25 (2).

Reinhart, Carmen M (1999): "The Anatomy of Financial Crises". Seminar Paper for the Seminar "Capital Flow Volatility, Contagion and Crises Management' at the University of Maryland.

UNCTAD (1999): "World Investment Report 1999: Foreign Direct Investment and the Challenge of Development". United Nations.

White, William R (1999): "Evolving international financial markets: some implications for central banks". *BIS Working Papers*, No. 66, April.

Measuring international volatility spillovers

Magnus Dahlquist, Peter Hördahl and Peter Sellin[1]

1. Introduction

Since the early 1980s, there has been a trend to globalisation in international financial markets as investors' portfolios have become more internationally diversified.[2] Perhaps as a result of this, volatility has been closely synchronised across national bond markets since the mid-1980s (Borio and McCauley (1996)). Moreover, we have witnessed increased comovements of interest rates across national markets that do not seem to be fully explicable by fundamental domestic determinants. As an example, we have the increase in long-term rates in Europe and Japan following the Fed's tightening of monetary policy in early 1994 in spite of the fact that these economies were considerably weaker than the US economy at that time.[3]

The observations made above raise (at least) two important questions. First, where do the shocks originate – in the large bond markets or in the small markets themselves – and how are they transmitted from one market to another? Interest rates could move either in response to global events that affect all national markets or they could be primarily driven by local events. Second, do markets move together at exactly those times when investors do not want them to, i.e. when volatility is high? If this were the case, the benefits of international portfolio diversification would be reduced.

In this paper we consider the transmission of shocks from the United States and German bond markets to the Swedish bond market during the recent 1993–98 period of floating exchange rates. More specifically, we characterise the behaviour of conditional variances and covariances on German, Swedish and US bonds. The emphasis is on volatility spillovers from two larger markets – Germany and the United States – to a small market – Sweden. Furthermore, we address the question of whether markets become more correlated during periods of high volatility. Another question is how persistent are these correlations and what is of importance for longer horizon correlations?

It is well established that financial data, at least when sampled monthly or more frequently, exhibit time-varying second moments. The parsimonious autoregressive conditional volatility (ARCH) modelling seems to be able to capture this variation in second moments.[4] Univariate time-series models of asset returns have emphasised stylised facts in the form of volatility clustering and the persistence in volatility. More recently, there have also been studies employing multivariate ARCH models.[5] Unlike these studies, our focus will not only be on the conditional variances of returns, but also on the conditional covariation of returns. In addition, most previous studies have been concerned

---

1 Magnus Dahlquist is an assistant professor at the Stockholm School of Economics and the CEPR, and Peter Hördahl and Peter Sellin are economists at the Bank of Sweden.

2 See, for example, Davis (1991), Frankel (1992), Mussa and Goldstein (1993) and Tesar and Werner (1995).

3 There is also anecdotal evidence that, at least in the short term, bond traders react to developments in the major markets rather than to the fundamentals in the country of relevance.

4 See Bollerslev et al. (1992) for a survey of the empirical ARCH literature. An extensive review of the methodology is given by Bollerslev et al. (1994).

5 Engle et al. (1990) employ factor ARCH models in their exploration of common features in returns on US bonds with different maturities. Ng et al. (1992) investigate US stock returns in a similar setting. Furthermore, Diebold and Nerlove (1989) analyse exchange rate movements in this context. The interaction between volatility and the transmission of volatility across international stock markets is considered by Hamao et al. (1990), Engle et al. (1990), Lin et al. (1994), and King et al. (1994), among others.

with equity markets rather than fixed income markets. For portfolio managers, worldwide bond markets should be of equal or greater importance.

Often, the number of parameters in multivariate models increases dramatically with the dimension of the system, making them intractable. It is therefore necessary to use a specification that reduces the number of parameters to estimate, but is still flexible enough to capture the dynamics and features of the data. In this paper, we use an ARCH model which allows local as well as global influences. The idea behind the parameterisation is that a few common economic factors determine asset prices. This is implemented on both covariances between returns and on the structure for the expected returns. Hence, this kind of model places restrictions – consistent with the basic idea – on the conditional means and conditional variances for the returns.

The paper is organised as follows. In Section 2, we give a brief description of the data and a preliminary analysis which serves as a motivation for the paper. Our empirical model is formulated in Section 3. The results from the estimation of the basic model together with diagnostics are presented in Section 4. A characterisation of conditional variances as well as the derived conditional correlations is given in Section 5. Finally, we offer some concluding comments in Section 6.

2. Data and some preliminary analysis

2.1 Data

We consider holding returns for the period 20 October 1993 – 22 December 1998 on three national bond markets: Germany, the United States and Sweden. Ideally, we would like to consider more countries but our parsimonious parameterisation, described in the next section, only allow for a small set of countries. The choice of the larger markets, Germany and the United States, is meant to capture the common global economic factors affecting returns.

The bonds have a maturity of 10 years. The sample is weekly and the holding period is one week. The holding returns for the 10-year bonds are computed from constructed zero coupon bond rates obtained using Svensson's (1995) extension of the Nelson and Siegel (1987) model. The rates are collected at around European market closing time every Tuesday, or Wednesday if Tuesday is a holiday. The source is the *Sveriges Riksbank*.

Figure 1. Swedish, German and US 10-year interest rates

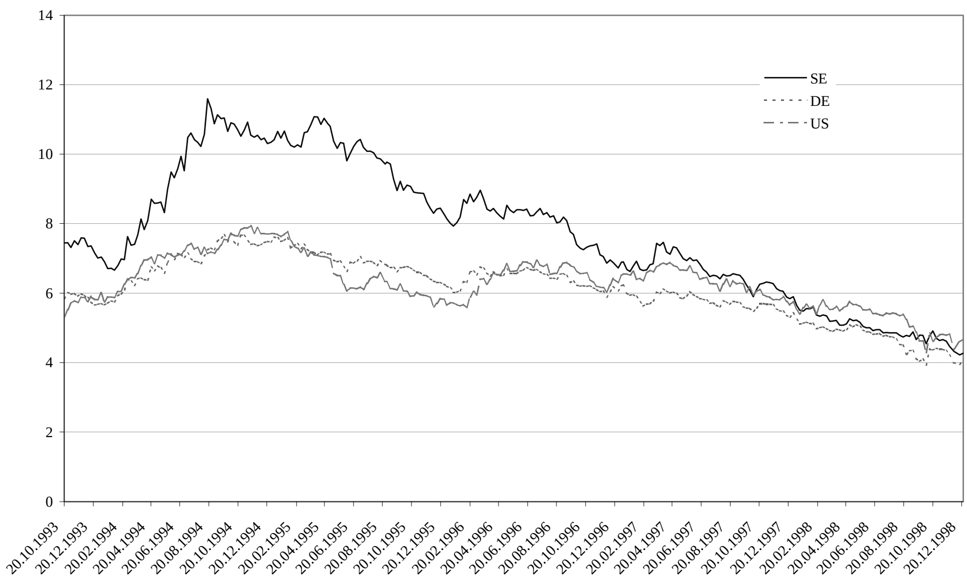


Figure 2a. Weekly returns on Swedish 10-year bonds

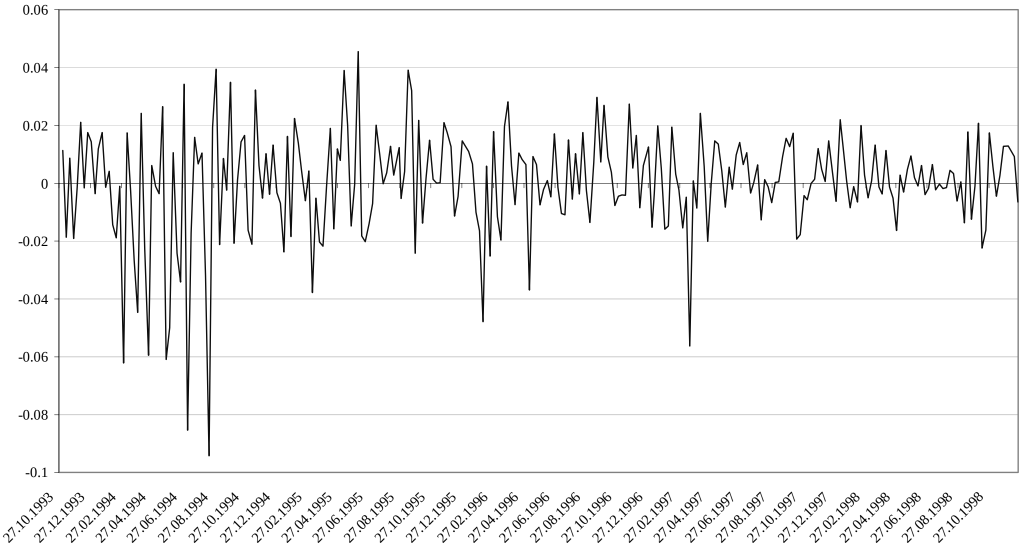


Figure 2b. Weekly returns on German 10-year bonds

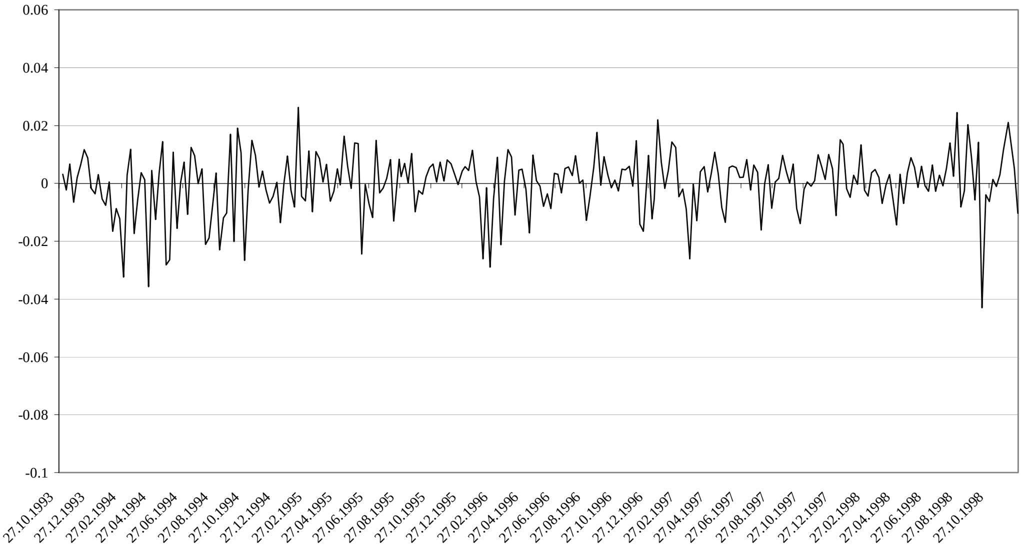
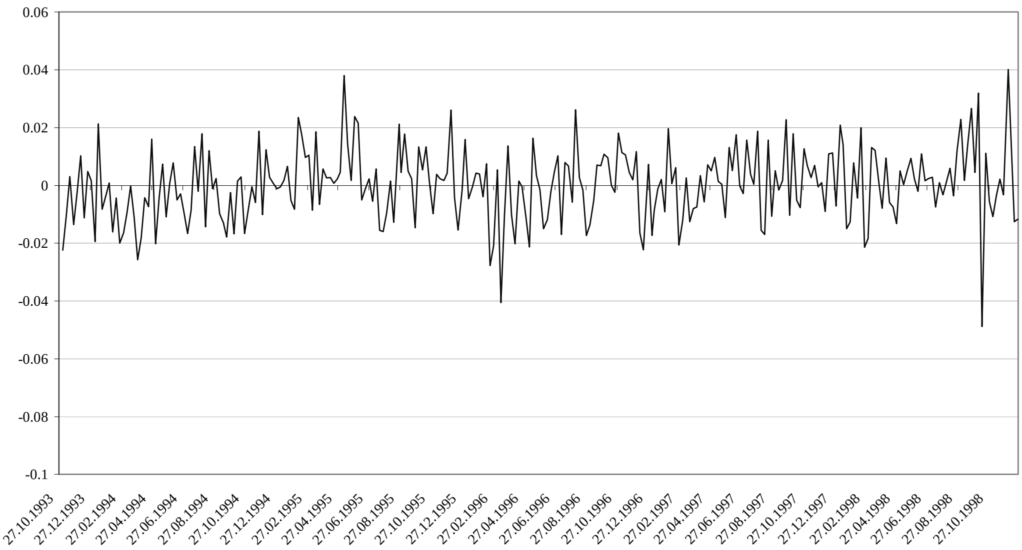


Figure 2c. Weekly returns on US 10-year bonds



Holding returns are constructed by taking the difference between the logarithm of the prices of the constructed 10-year zero coupon bonds and the10-year-minus-one-week bonds one week later. We use local returns. That is, the returns are not converted to a specific currency, but can rather be seen as (perfectly) hedged returns. We are thus abstracting from influences due to variations in exchange rates.

The 10-year interest rates on Swedish, German and US bonds are shown in Figure 1. The Swedish 10-year interest rate has clearly converged toward the lower paths followed by the German and US interest rates. During the turbulence in early 1994, there was a strong increase in the Swedish 10-year rate, which then remained at about 4 percentage points above the German and US rates for most of 1994–95. But as Swedish economic policy gained credibility among investors, the interest rate gradually declined. During most of 1998, the Swedish rate was close to the German rate and lower than the US rate.

In Figures 2a–c, we depict the weekly returns on 10-year bonds in Sweden, Germany and the United States. We use the same scales to facilitate comparisons. It is evident that the Swedish returns are more volatile than the German and US returns, especially during the earlier part of the sample. It is more difficult to see whether volatility is positively correlated across markets. We will study this question more carefully below.

2.2 Some preliminary results

This section serves to illustrate some of the interdependencies among the three national bond markets. We are primarily interested in whether, and if so to what extent, volatility in one market spills over and contributes to volatility in another market. For investors, interested in diversifying the risk in their portfolios internationally, it is of importance to know how correlations vary over time. It is especially important that markets are not more correlated in times of high volatility, since this would mitigate the benefits of diversification.

In Figures 3a–b, we look at how the volatility of interest rates and returns in the three markets has evolved over time. We do this by computing rolling standard deviations using 20 weeks of data for each observation. There seems to be some positive covariation among the series depicted in Figures 3a–b. There also seems to be a downward trend in volatility in the Swedish bond market during this period.

To see if we can detect if and when there is a shift in volatility, in Figures 4–6 we present the cumulative sum of squares, C_k, and the centred cumulative sum of squares, $\sqrt{T/2}D_k$, of the return series for the three markets. These measures are defined as follows:

(1) $$C_k = \sum_{t=1}^{k} \varepsilon_t^2$$

where ε_t is the residual from a regression of the return on a constant and lagged return, and

(2) $$D_k = \frac{C_k}{C_T} - \frac{k}{T}$$

for $k = 1,...,T$, with $D_0 = D_T = 0$. The reason for de-meaning and filtering out autocorrelation in the return series is that this makes possible correct statistical inference regarding $\sqrt{T/2}D_k$. This quantity should oscillate around zero for series with homogeneous variance. If the maximum absolute value at date k, $\max_k \left| \sqrt{T/2}D_k \right|$, exceeds the critical boundary value of 1.3, we can with 95% confidence say that there has been a shift in variance at date k.[6] We have marked these boundaries in Figures 4–6. A peak indicates a downward shift and a trough an upward shift in volatility.

---

[6] The critical values for different sample sizes are tabulated in Inclán and Tiao (1994).

Figure 3a. Rolling standard deviations: 10-year interest rates

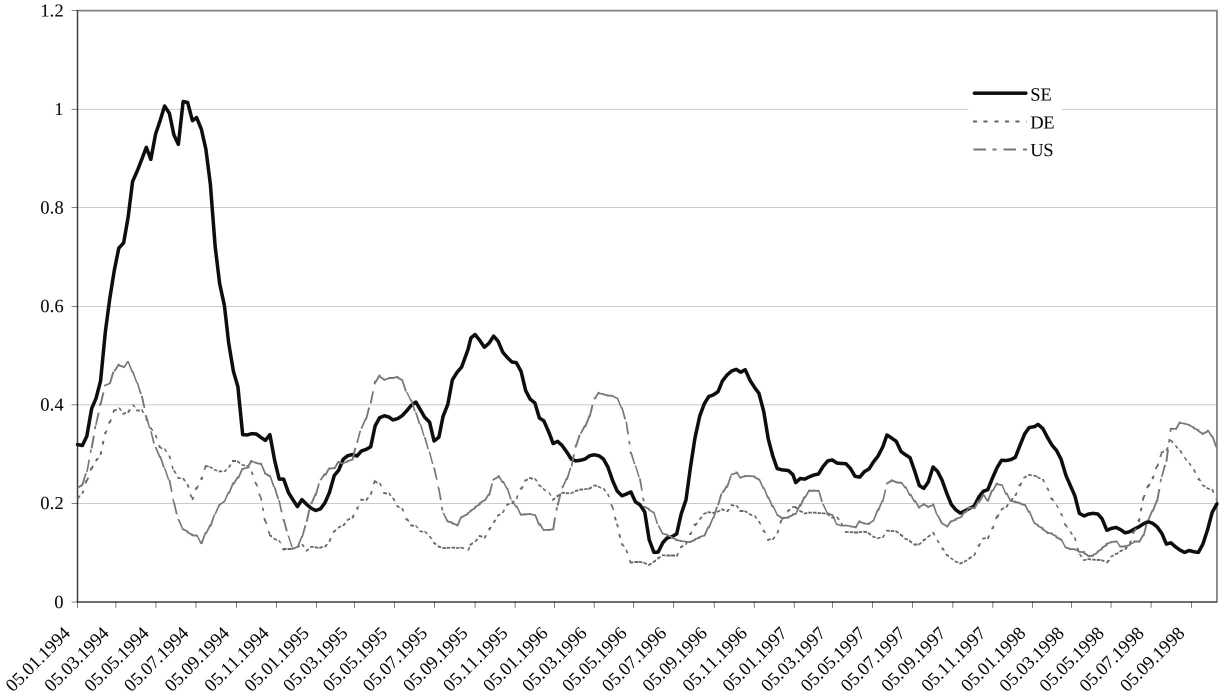
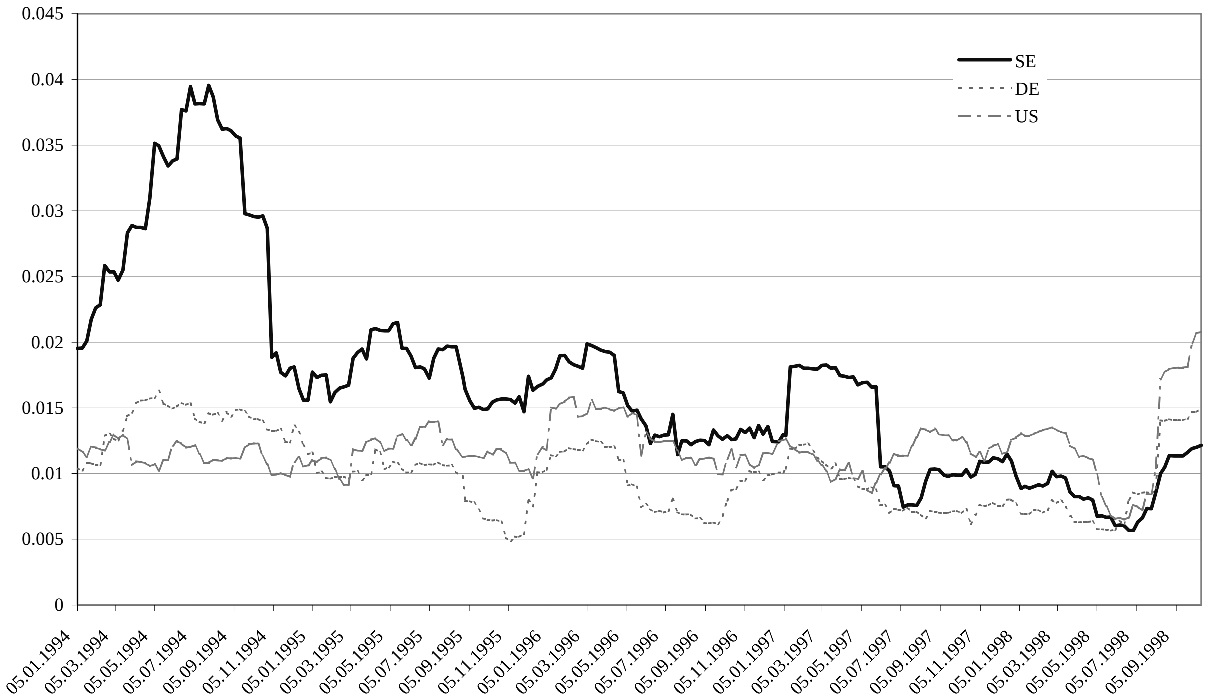


Figure 3b. Rolling standard deviations: weekly returns on 10-year bonds



Inclán and Tiao (1994) present an algorithm, based on the centred cumulative sum of squares, for detecting all the shifts in variance that have occurred in a time series. First, the maximum trough or peak is found, which then represents a candidate breakpoint. In the Swedish series, we find a maximum significant departure on 16 November 1994 (Figure 4b). Then, the series before and after this point are investigated (Figure 4c–d) in order to find candidates for the first and last breakpoints

Figure 4a. Cumulative sum of squares: Sweden

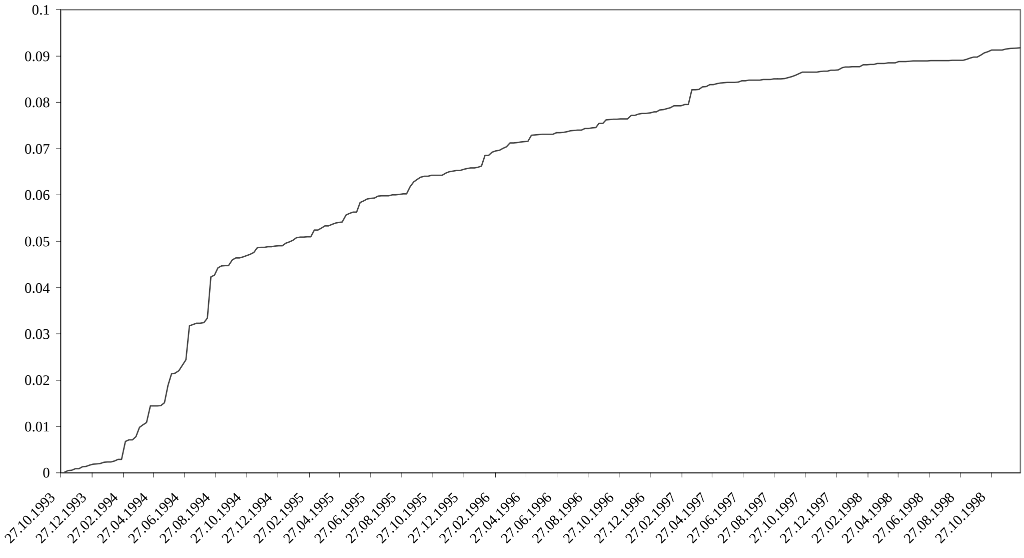


Figure 4b. Centred CSS: Sweden

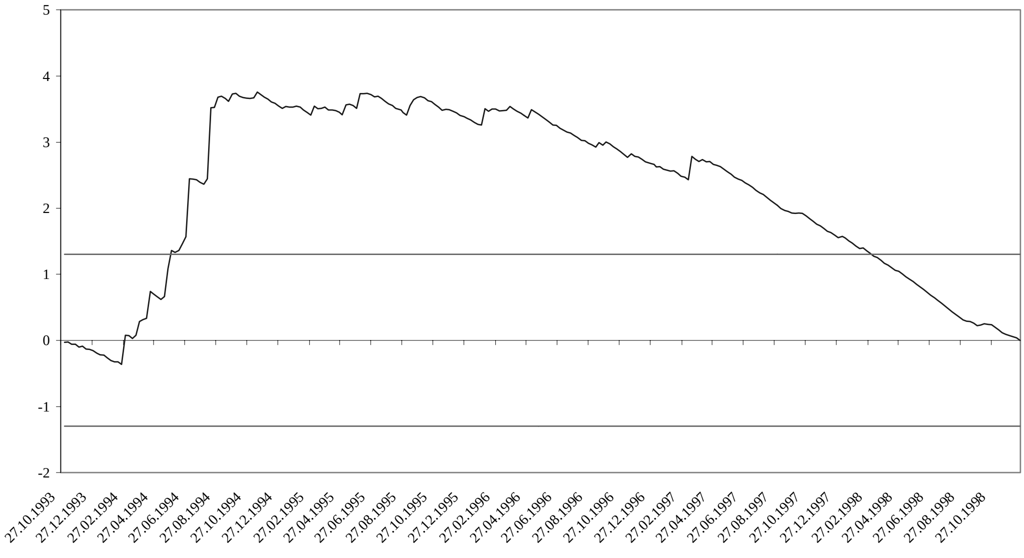


Figure 4c. Centred CSS: Sweden 3 Nov 1993 - 16 Nov 1994

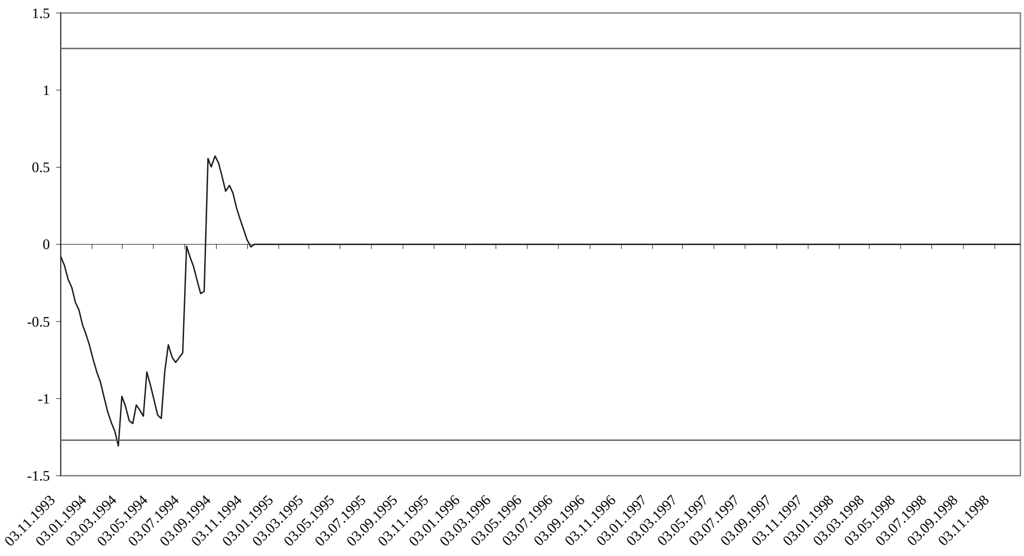


Figure 4d. Centred CSS: Sweden 23 Nov 1994 - 22 Dec 1998

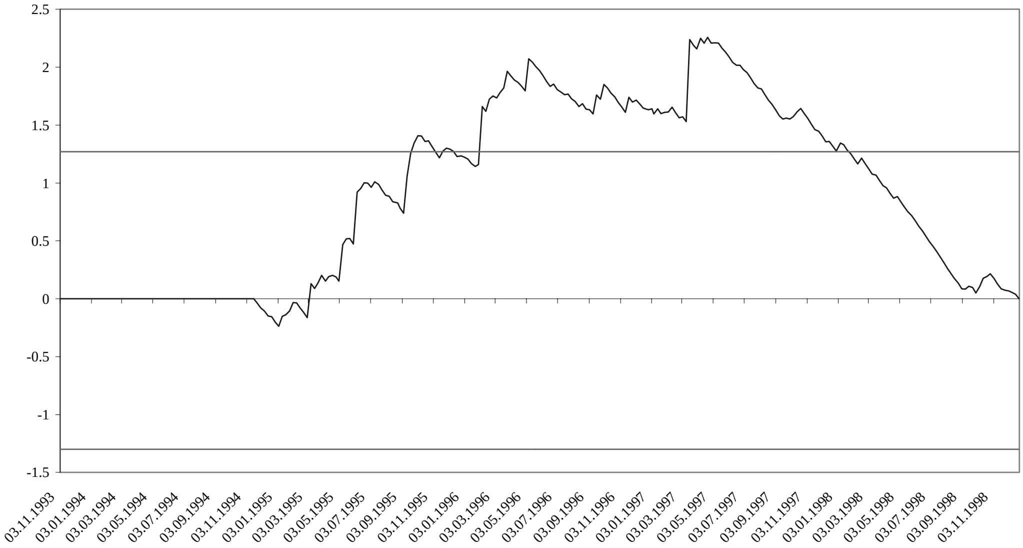


Figure 4e. Centred CSS: Sweden 29 April 1997 - 22 Dec 1998

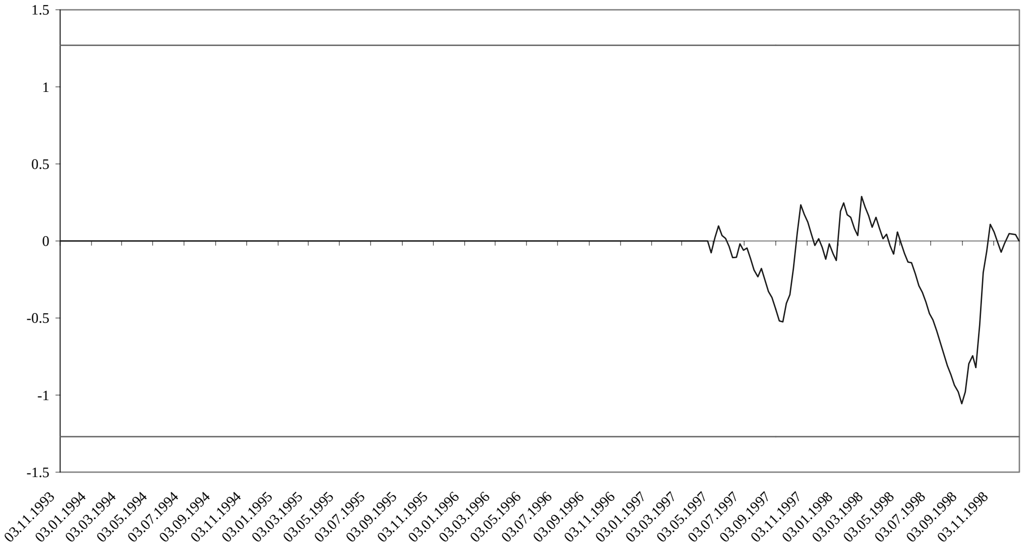


Figure 4f. Centred CSS: Sweden 2 March 1994 - 22 April 1997

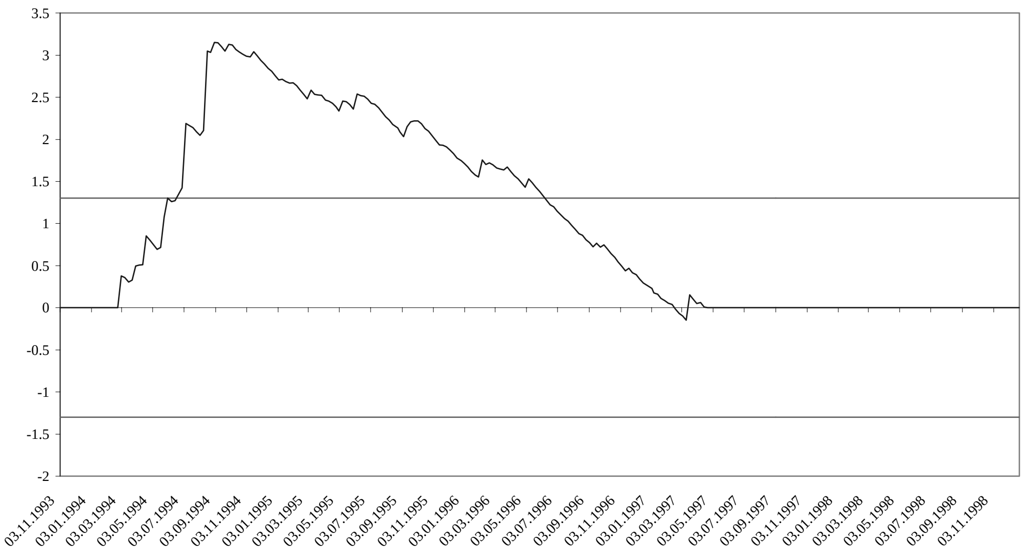


Figure 4g. Centred CSS: Sweden 2 March 1994 - 31 Aug 1994

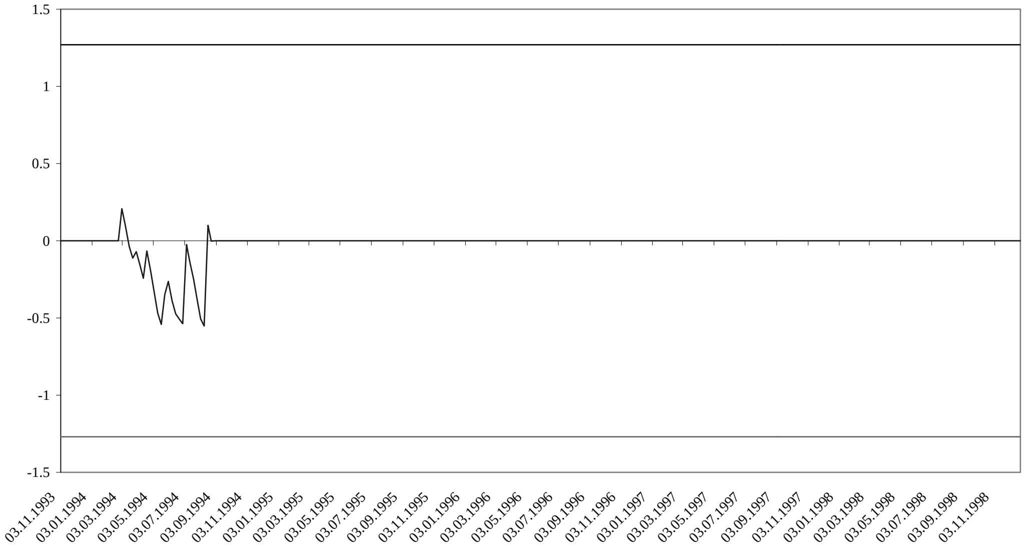


Figure 4h. Centred CSS: Sweden 7 Sept 1994 - 22 April 1997

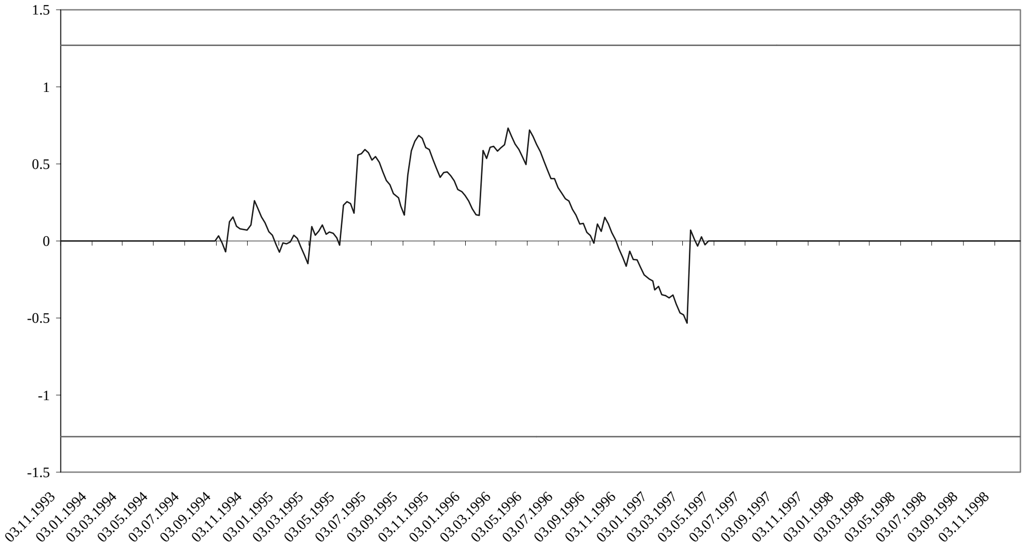


Figure 5a. Cumulative sum of squares: Germany

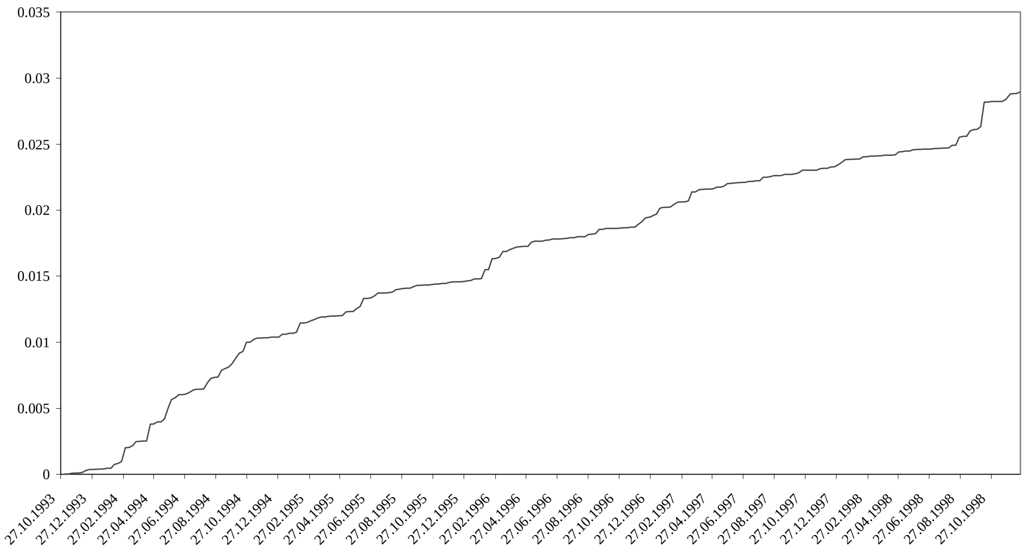


Figure 5b. Centred cumulative sum of squares: Germany

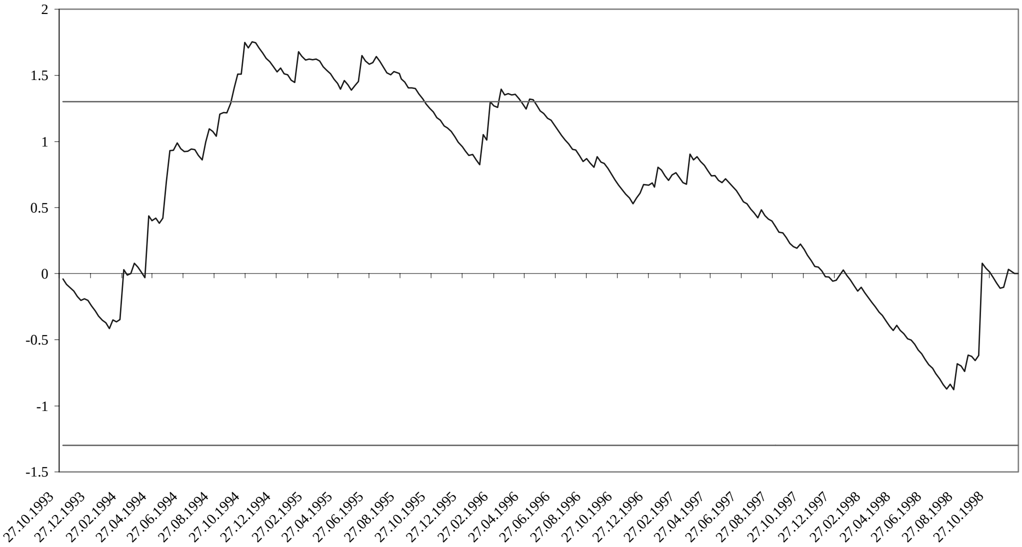


Figure 5c. Centred CSS: Germany 3 Nov 1993 - 26 Oct 1994

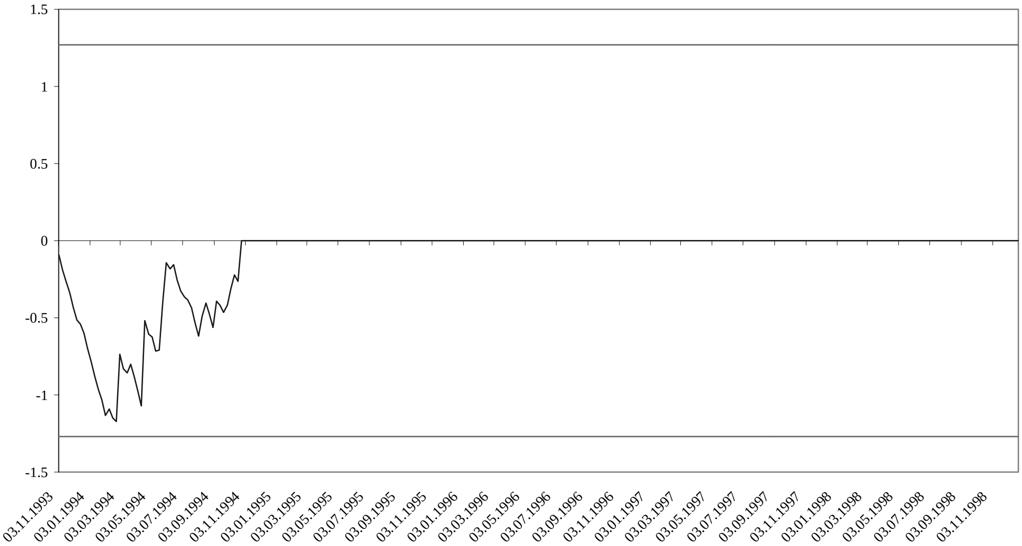


Figure 5d. Centred CSS: Germany 2 Nov 1994 - 22 Dec 1998

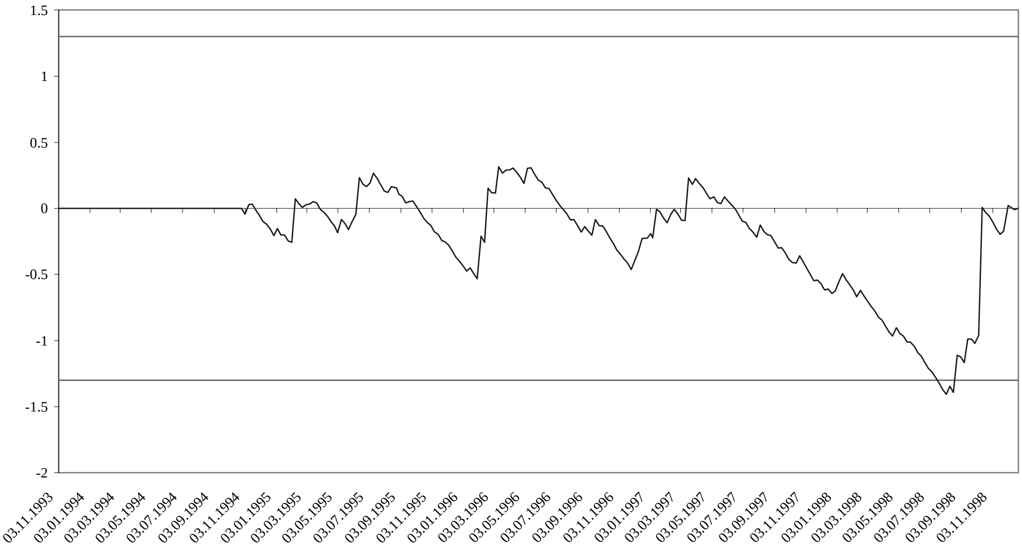


Figure 5e. Centred CCS: Germany 2 Nov 1994 - 18 Aug 1998

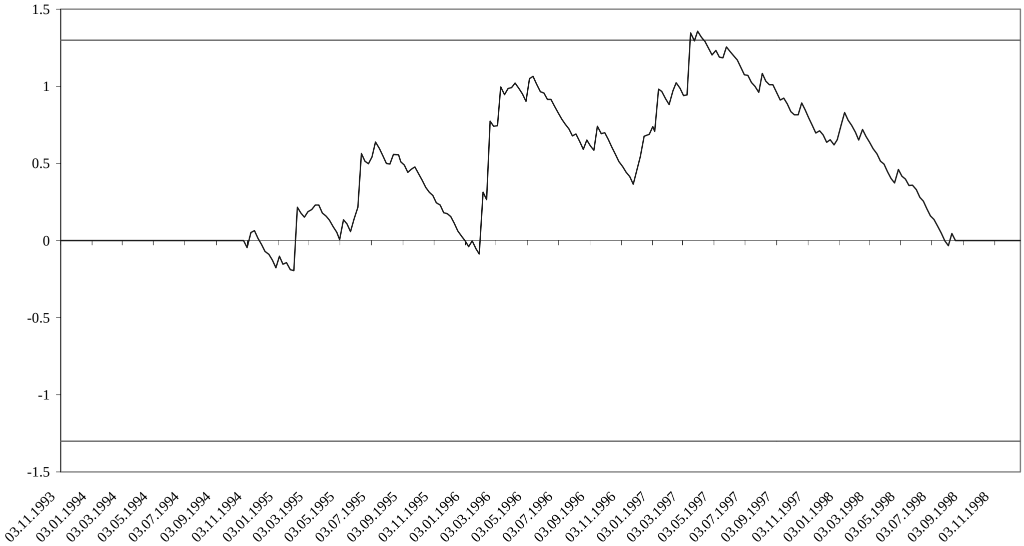


Figure 5f. Centred CSS: Germany 2 Nov 1994 - 1 April 1997

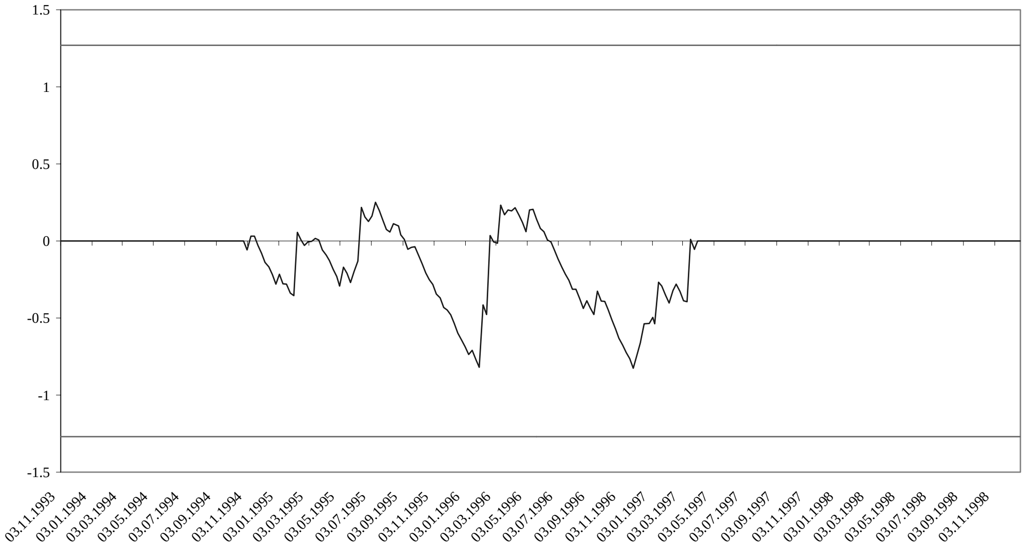


Figure 5g. Centred CSS: Germany 8 April 1997 - 18 Aug 1998

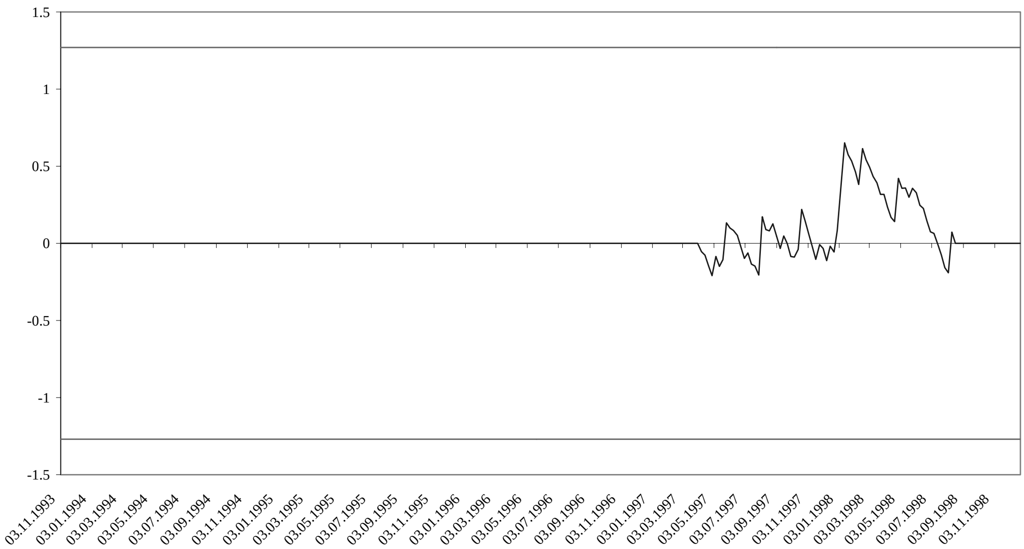


Figure 6a. Cumulative sum of squares: US

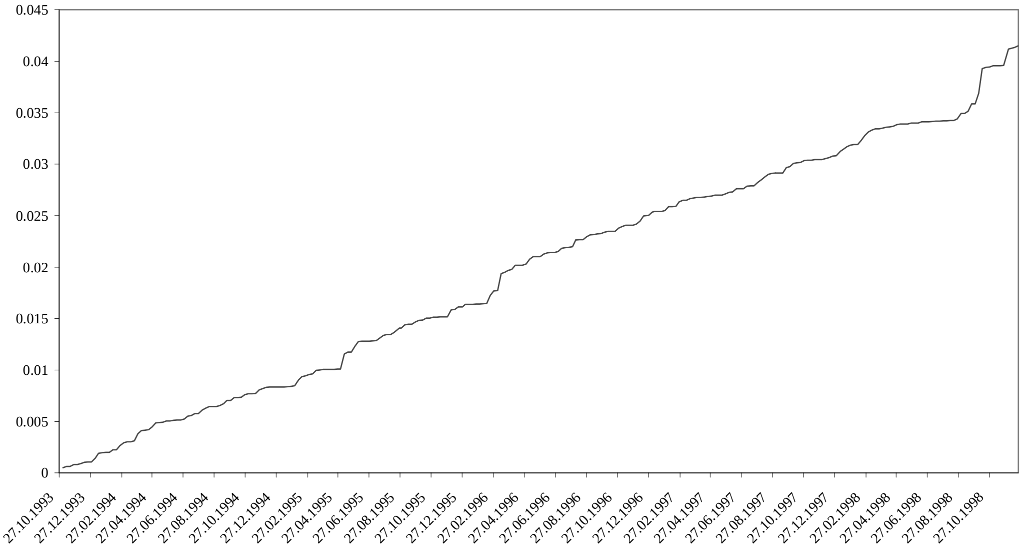


Figure 6b. Centred cumulative sum of squares: US

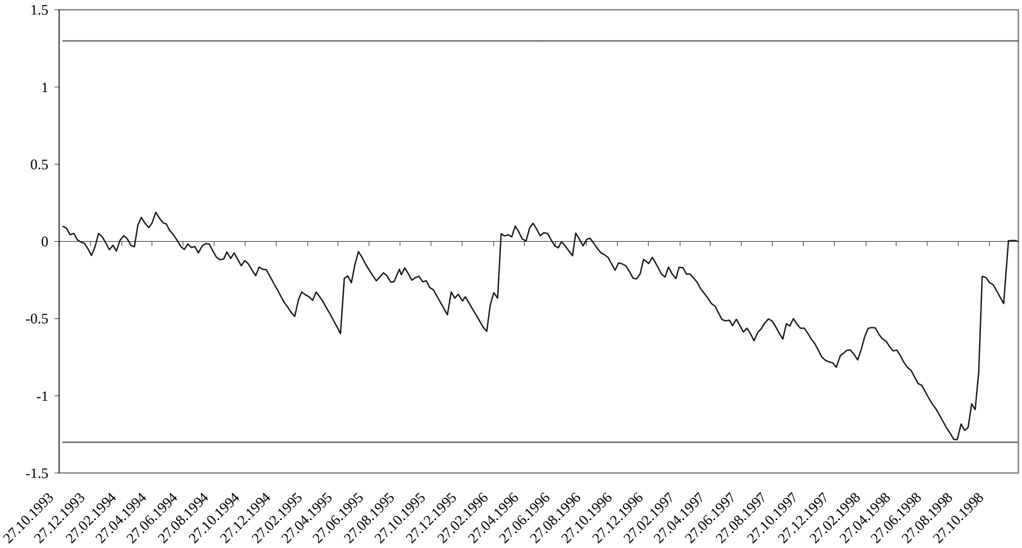
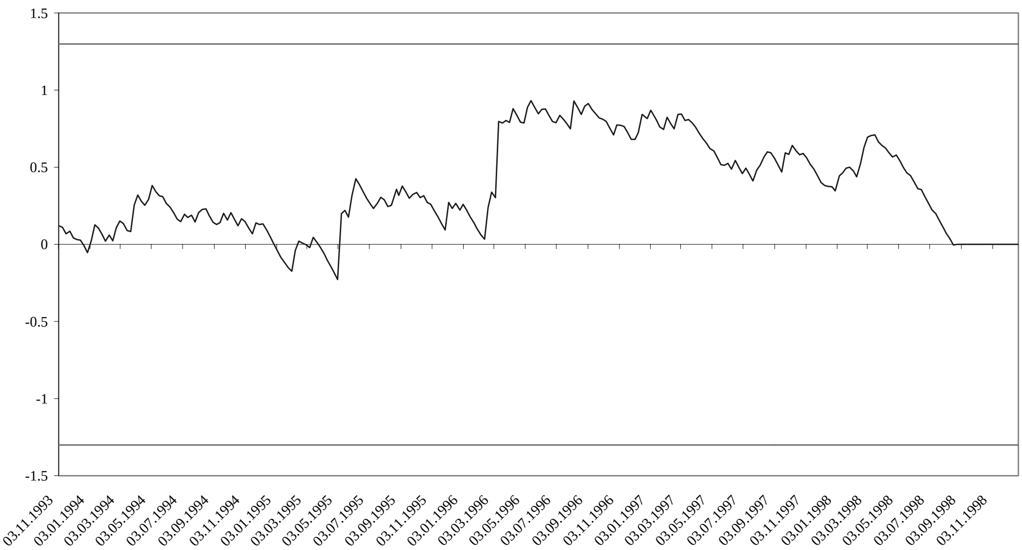


Figure 6c. Centred CSS: US 3 Nov 1993 - 25 Aug 1998



(23 February 1994 and 22 April 1997). We take 23 February 1994 as the first breakpoint, since there are too few observations to allow us to find a possible earlier breakpoint. In Figure 4e, it is confirmed that 22 April 1997 is the last breakpoint, since there are no violations of the 95% confidence intervals. The analysis is then repeated for the new series starting at the first breakpoint and ending at the last breakpoint. We iterate in this manner until all the breakpoints in the series are found. The same procedure is followed in investigating the German and US series in Figures 5 and 6 respectively. We detect a total of seven breaks in the three series: three (or possibly four) in the Swedish series, three in the German series, and one in the US series (see Table 1).

Using the Inclán and Tiao algorithm, the first shift we detect is an upward shift in Swedish volatility on 23 February 1994. This is followed by a downward shift later the same year, on 31 August. The third shift occurs in the German market on 26 October 1994, when volatility shifts down. In April 1997, there is another downward shift in volatility in the German market in the first week of the month (1 April), followed by a downward shift in the Swedish market on 22 April. There is an upward shift in volatility in the German market on 18 August 1998, immediately followed by an upward shift in the US market on 25 August (at the 80% confidence level, there is also a shift in the Swedish market on 1 September). These shifts took place in the wake of the Russian debt crisis. We note that some of the shifts in volatility occur at around the same time in at least two of the markets studied, while other shifts are market-specific.

Table 1
Weeks with a shift in volatility

Sweden	Germany	United States
23 February 1994 *(up)*		
31 August 1994 *(down)*		
	26 October 1994 *(down)*	
22 April 1997 *(down)*	4 April 1997 *(down)*	
1 September 1998 *(up)*	18 August 1998 *(up)*	25 August 1998 *(up)*

In addition to investigating concurrent shifts in volatility, it is also of interest to look at more short-term synchrony. Let us first focus on contemporaneous large interest rate shocks in the three markets. In Table 2, we report large changes in interest rates defined as greater than 30 basis points in absolute value, that is, if the change in interest rates during a week has been larger than 30 basis points in at least one of the markets we enter the changes for all markets in that week in Table 2. However, for clarity of exposition we do not report changes of less than 15 basis points. For the same reason, changes greater than 30 basis points are in boldface. There is only one instance when a change in one of the large markets is not associated with a large change in the smaller Swedish market (3 December 1998). In most cases, a large change in the Swedish interest rate is contemporaneous with a large change in the US or German rate, or both. But this is not always the case, which suggests that domestic factors also play an important role. The most striking example of this is 11 August 1994, when the Swedish Riksbank announced an increase in its repo rate. This was the first rate increase following a period of easing and came as something of a surprise to the market, resulting in the 102 basis point increase in the 10-year interest rate in the following week.

Another way to investigate short-term synchrony is to use the same technique as above to compute rolling correlations among the series. These are shown in Figures 7a–b. During most of the period, it looks as if the Swedish market is more highly correlated with the German than with the US market. We also note that the correlations vary a great deal over time, which makes it more difficult to distinguish possible trends in the correlations. But with the exception of the period of high correlation between the Swedish and German markets in 1994, the correlations seem to have trended upwards during the period.

To investigate the question of a possible interaction between volatility and correlations, we sort rolling 20-week return volatility from the lowest to the highest. Then, the correlations of the returns are ordered correspondingly (so that the dates are matched). Finally, the averages of the correlations for each quartile are computed. The results are shown in Figures 8a–c. The overall impression from these figures is that the correlation between the returns on a large and small bond market is decreasing in the volatility of the small market but increasing in the volatility of the large market. In Figure 8a, the correlation between Swedish and US returns is negatively related to the volatility in the Swedish market. The relation regarding the correlation between Swedish and German returns is not as clear. When the German market is the reference market the negative relation is weaker, as seen in Figure 8b. The evidence presented in Figure 8c tells us that volatility in the US market is positively related to the correlations with returns in the other two (smaller) markets.

The above preliminary results warrant a further assessment of the time variation in second moments. We therefore continue our analysis with the estimation of a multivariate ARCH model, which is potentially able to accommodate the features documented above.

Table 2
Large changes in interest rates

Week	Sweden	Germany	United States
2 March 1994	**66**	**32**	
30 March 1994	**45**		24
6 April 1994	**–30**		
20 April 1994	**62**	**38**	
18 May 1994	**–30**	–15	
25 May 1994	**67**	**31**	
1 June 1994	**49**	24	
22 June 1994	**35**		
29 June 1994	**–41**		
6 July 1994	**96**		16
10 August 1994	**35**	23	19
17 August 1994	**102**	17	–17
31 August 1994	**–43**		
28 September 1994	**–40**	–20	
16 November 1994	**–38**		
8 March 1995	**41**		
9 May 1995	**–43**	–18	**–40**
6 June 1995	**–51**	–14	–18
12 September 1995	**–44**		
19 September 1995	**–33**		
6 February 1996	**50**	26	
20 February 1996	27	**30**	**31**
12 March 1996	20	23	**45**
26 March 1996	**–30**		–15
7 May 1996	**39**	17	20
17 September 1996	**–33**	–19	
19 November 1996	**–31**		
18 March 1997	**59**	26	
6 October 1998	–24	–17	**–34**
13 October 1998	23	**46**	**57**
3 December 1998		–22	**–43**

Note: A large change is defined as a change greater than 30 basis points in absolute value. Changes smaller than 15 basis points are not shown in the table.

Figure 7a. Rolling correlations: 10-year interest rates

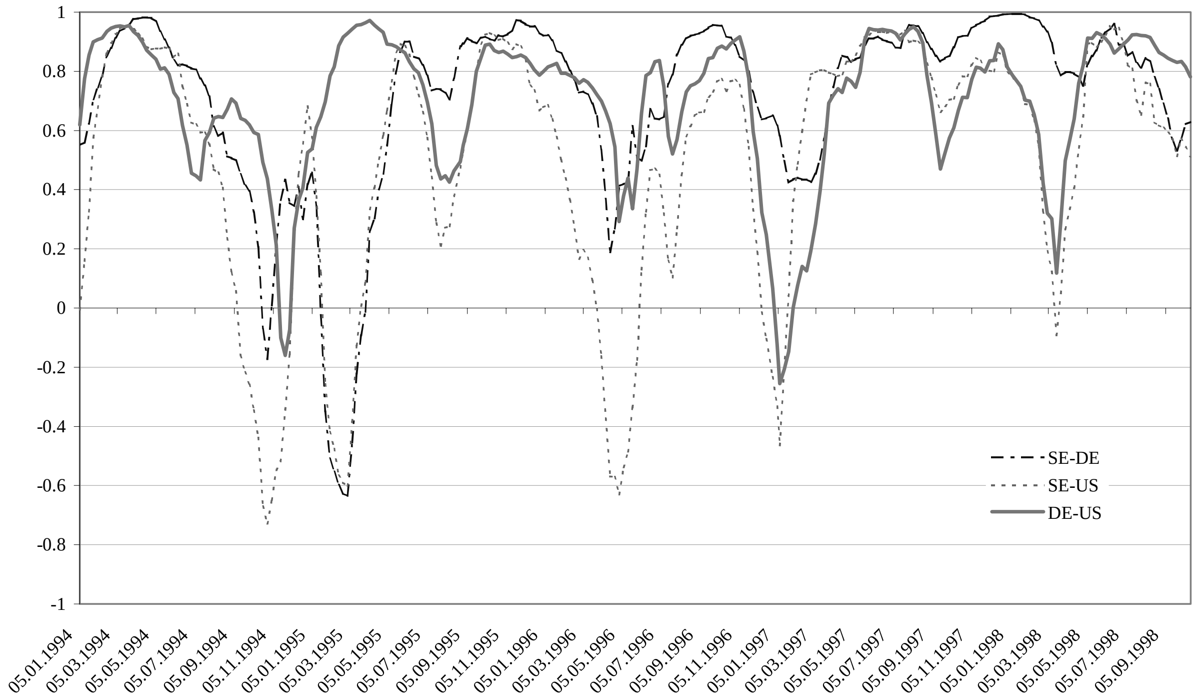


Figure 7b. Rolling correlations: weekly returns on 10-year bonds

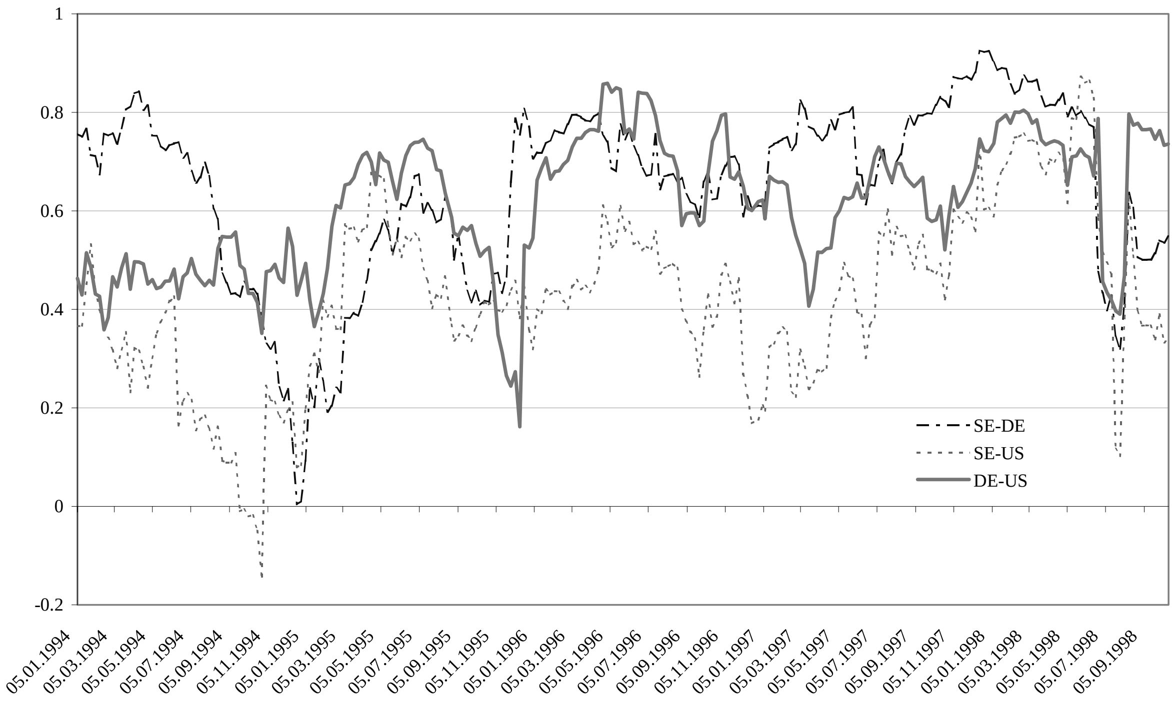


Figure 8a. Average correlations sorted on Swedish volatility

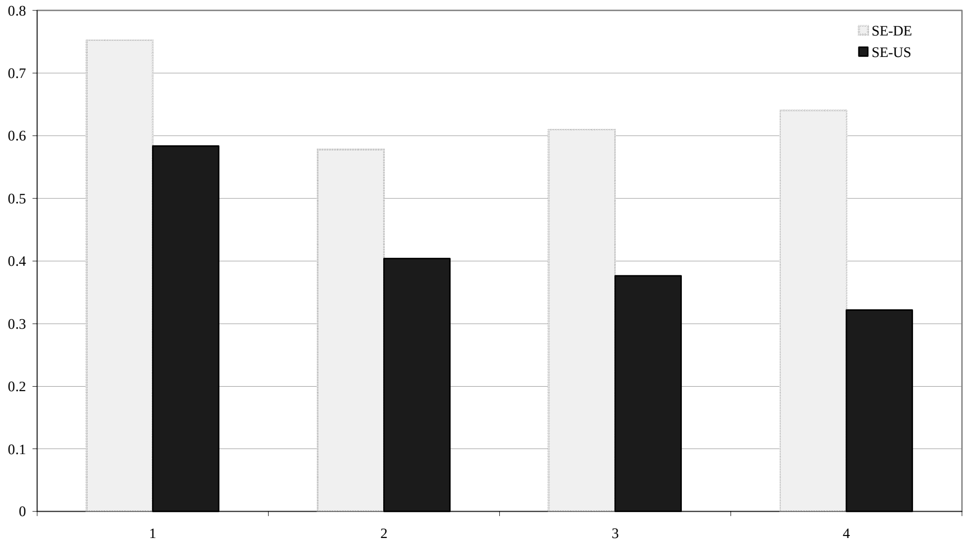


Figure 8b. Average correlations sorted on German volatility

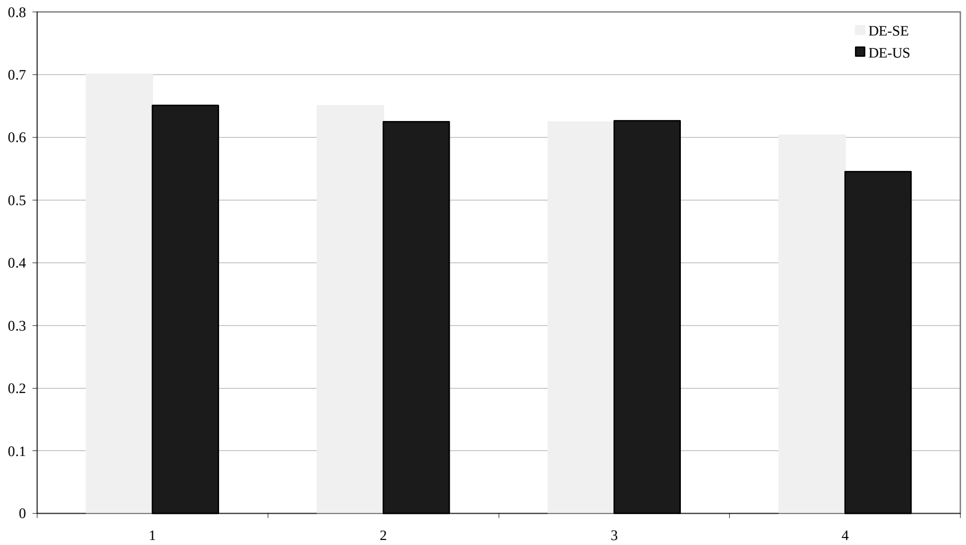
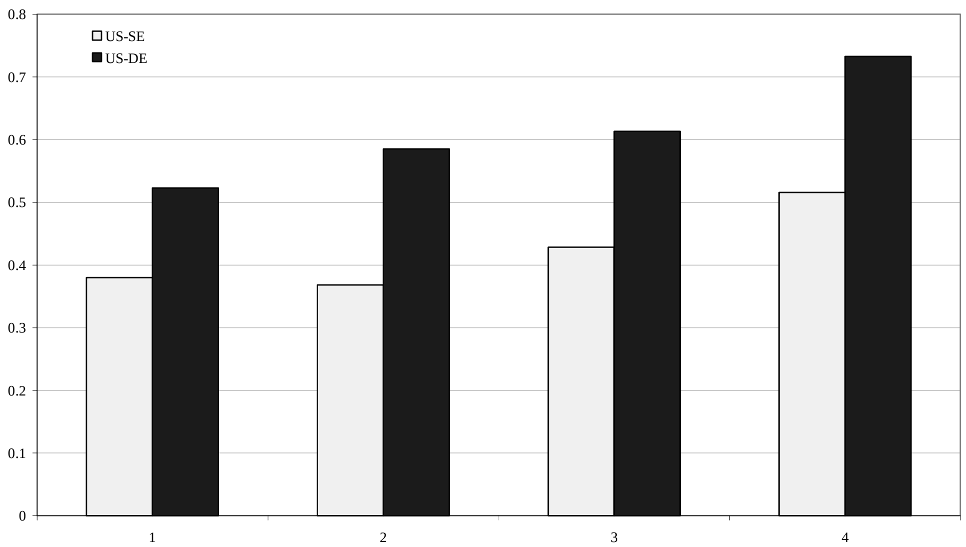


Figure 8c. Average correlations sorted on US volatility



3. The empirical model

We need a model that is flexible enough to capture the time-varying nature of the interdependencies between the bond markets, as indicated above. A multivariate ARCH model should be able to capture the observed patterns to some extent.[7]

3.1 Conditional means

A straightforward linear model will be used for the conditional means. Let R_t^i denote the return on the ith bond market, where $i = DE$ (Germany), US (United States) or SE (Sweden). We consider the following moving average (MA) specification for Germany

(3) $$R_t^{DE} = \theta_0^{DE} + \varepsilon_t^{DE} + \theta_1^{DE}\varepsilon_{t-1}^{DE} + \theta_2^{DE}\varepsilon_{t-1}^{US}$$

and for the United States

(4) $$R_t^{US} = \theta_0^{US} + \varepsilon_t^{US} + \theta_1^{US}\varepsilon_{t-1}^{DE} + \theta_2^{US}\varepsilon_{t-1}^{US}$$

This specification is consistent with the idea that price spillovers do not necessarily have to be related to volatility spillovers or the fact that shocks in the two markets are correlated. For Swedish returns, the model is formulated such that price shocks from all markets could be of importance,

(5) $$R_t^{SE} = \theta_0^{SE} + \varepsilon_t^{SE} + \theta_1^{SE}\varepsilon_{t-1}^{DE} + \theta_2^{SE}\varepsilon_{t-1}^{US} + \theta_3^{SE}\varepsilon_{t-1}^{SE}$$

In the next section, we will discuss how to model the error terms, allowing for time variation, and the link to the conditional second moments in the above pricing equations.

3.2 Conditional variances

We will use a model suggested by Engle and Kroner (1995), known as the BEKK model. This model is a special case of the more general VEC representation of a multivariate generalised ARCH model. The advantage of the BEKK model for conditional covariances is that it guarantees positive definite conditional covariance matrices under weak conditions. Moreover, compared with other models it uses few parameters, but still allows for conditional correlations and is able to capture potential cross-volatility interactions as well. For tractability, the model is here restricted to be of order (1,1). The specification below allows us to simultaneously model conditional variances, covariances and correlations.

Let $\varepsilon_t = \left[\varepsilon_t^{DE}\varepsilon_t^{US}\varepsilon_t^{SE}\right]'$ denote a combined error term from the conditional mean specifications. In the general BEKK model we consider, the dynamic for the conditional covariance matrix is given by

(6) $$H_t \equiv E\left(\varepsilon_t\varepsilon_t' \middle| I_{t-1}\right) = \Omega'\Omega + A'\varepsilon_{t-1}\varepsilon_{t-1}'A + B'H_{t-1}B$$

where Ω is a 3 x 3 upper triangular matrix of parameters, and A and B are 3 x 3 matrices of parameters. We can impose some additional restrictions on the model. We make the innocuous assumption that there is no spillover from the small Swedish bond market to the larger US and German markets. This results in the following parameterisation of the A and B matrices

$$A = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \text{ and } B = \begin{bmatrix} b_{11} & 0 & 0 \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}$$

---

[7] We started by estimating univariate GARCH models for each market separately allowing for shifts in variance, in agreement with the findings reported in the previous section. However, the shift coefficients turned out not to be statistically significant in the GARCH framework.

Note that the general model can be written in a vectorised form – a vech representation. Let vech(.) denote the vectorisation operator which stacks the elements on and below the diagonal of a matrix (i.e. the unique elements in a covariance matrix). The BEKK model can then be written as

$$\text{(7)} \qquad \text{vech}(H_t) = \tilde{\Omega} + \tilde{A}\text{vech}(\varepsilon_{t-1}\varepsilon'_{t-1}) + \tilde{B}\text{vech}(H_{t-1})$$

where $\tilde{\Omega}$, $\tilde{A}$ and $\tilde{B}$ are matrices which are expressed in terms of the Ω, A and B matrices (see the Appendix). Bollerslev and Engle (1993) show that this system is covariance stationary if and only if the eigenvalue for $\tilde{A} + \tilde{B}$ with the maximum norm is strictly less than one.

3.3 Estimation

The combined error term is assumed to be conditionally multivariate normal distributed, that is,

$$\text{(8)} \qquad \varepsilon_t | I_{t-1} \sim N(0, H_t)$$

Under the assumption of conditional normality, the log-likelihood function for observation t can be expressed as

$$\text{(9)} \qquad L_t(\phi) = -\frac{3}{2}\ln(2\pi) - \frac{1}{2}\ln|H_t(\phi)| - \frac{1}{2}\varepsilon_t(\phi)' H_t(\phi)^{-1}\varepsilon_t(\phi)$$

where φ denotes a combined parameter vector. The log-likelihood function over the sample (t = 1, 2, …, T) is thus

$$\text{(10)} \qquad L(\phi) = \sum_{t=1}^{T} L_t(\phi)$$

and the parameter vector is given by

$$\text{(11)} \qquad \phi = \left[\phi^i_j, \omega_{ij}, a_{ij}, b_{ij}\right]'$$

where the ϕ^i_js are parameters in the conditional means, and ω_{ij}, a_{ij} and b_{ij} are typical elements on the Ω, A and B matrices, describing the conditional variances.

The maximum likelihood estimator of the parameters can be found by numerically maximising the likelihood. The estimation is done in a recursive fashion, where initial values of the conditional variances are set equal to the unconditional variances. The assumption of conditional normality is not always appropriate. It has, however, been shown that the so-called quasi maximum likelihood estimator is asymptotically normally distributed and consistent if the mean and variance functions are correctly specified. Robust standard errors can thus be calculated as in White (1982).

4. Baseline estimation

4.1 Basic model

We commence with an investigation of potential price spillovers. The estimated mean equations for the weekly returns on the 10-year bonds are

$$\text{(12)} \qquad R_t^{SE} = \underset{(0.0008)}{0.0034} + \varepsilon_t^{SE} + \underset{(0.1366)}{0.0318}\varepsilon_{t-1}^{DE} - \underset{(0.1054)}{0.0085}\varepsilon_{t-1}^{US} - \underset{(0.0590)}{0.0191}\varepsilon_{t-1}^{SE}$$

$$\text{(13)} \qquad R_t^{DE} = \underset{(0.0005)}{0.0022} + \varepsilon_t^{DE} - \underset{(0.0865)}{0.0375}\varepsilon_{t-1}^{DE} + -\underset{(0.0569)}{0.0652}\varepsilon_{t-1}^{US}$$

(14) $$R_t^{US} = \underset{(0.0006)}{0.0014} + \varepsilon_t^{US} - \underset{(0.0865)}{0.0043}\varepsilon_{t-1}^{DE} - \underset{(0.0684)}{0.1725}\varepsilon_{t-1}^{US}$$

with standard errors within parentheses below the estimated coefficients. It is clear that there are no price spillovers from the US bond market to either the German or Swedish markets. There is also no significant price spillover from the German market to the Swedish market.

Volatility spillovers will be discussed here in terms of the vech specification,

(15) $$\text{vech}(H_t) = \tilde{\Omega} + \tilde{A}\text{vech}(\varepsilon_{t-1}\varepsilon'_{t-1}) + \tilde{B}\text{vech}(H_{t-1}) + \tilde{C}\text{vech}(\eta_{t-1}\eta'_{t-1})$$

which facilitates interpretation of the parameters. The estimated parameters are reported below, with standard errors within parentheses below the estimated coefficients:

$$\tilde{A}\text{vech}(\varepsilon_{t-1}\varepsilon'_{t-1}) =$$

$$\begin{bmatrix}
\underset{(0.0614)}{0.1638} & \underset{(0.1692)}{-0.0542} & \underset{(0.1093)}{-0.3463} & \underset{(0.0267)}{0.0045} & \underset{(0.1616)}{0.0573} & \underset{(0.0982)}{0.1830} \\
0 & \underset{(0.0414)}{0.1273} & \underset{(0.0228)}{-0.0984} & \underset{(0.0623)}{-0.0211} & \underset{(0.0830)}{-0.1183} & \underset{(0.0443)}{0.1040} \\
0 & \underset{(0.0495)}{0.0771} & \underset{(0.0325)}{-0.0948} & \underset{(0.0397)}{-0.0128} & \underset{(0.0705)}{-0.0658} & \underset{(0.0497)}{0.1003} \\
0 & 0 & 0 & \underset{(0.0560)}{0.0989} & \underset{(0.0683)}{-0.1529} & \underset{(0.0256)}{0.0591} \\
0 & 0 & 0 & \underset{(0.0439)}{0.0599} & \underset{(0.0690)}{-0.1200} & \underset{(0.0313)}{0.0570} \\
0 & 0 & 0 & \underset{(0.0411)}{0.0363} & \underset{(0.0755)}{-0.0893} & \underset{(0.0430)}{0.0549}
\end{bmatrix}
\begin{bmatrix}
(\varepsilon_{t-1}^{SE})^2 \\
\varepsilon_{t-1}^{SE}\varepsilon_{t-1}^{DE} \\
\varepsilon_{t-1}^{SE}\varepsilon_{t-1}^{US} \\
(\varepsilon_{t-1}^{DE})^2 \\
\varepsilon_{t-1}^{DE}\varepsilon_{t-1}^{US} \\
(\varepsilon_{t-1}^{US})^2
\end{bmatrix}$$

$$\tilde{B}\text{vech}(H_{t-1}) =$$

$$\begin{bmatrix}
0.8362 & \underset{(0.1335)}{0.0184} & \underset{(0.0858)}{0.0253} & \underset{(0.0015)}{0.0001} & \underset{(0.0016)}{0.0003} & \underset{(0.0013)}{0.0002} \\
0 & \underset{(0.0340)}{0.8503} & \underset{(0.0318)}{0.0381} & \underset{(0.0679)}{0.0094} & \underset{(0.0417)}{0.0133} & \underset{(0.0022)}{0.0006} \\
0 & \underset{(0.0315)}{-0.0256} & \underset{(\;)}{0.8890} & \underset{(0.0020)}{-0.0003} & \underset{(0.0719)}{0.0094} & \underset{(0.0456)}{0.0134} \\
0 & 0 & 0 & \underset{(0.0692)}{0.8646} & \underset{(0.0619)}{0.0746} & \underset{(0.0029)}{0.0017} \\
0 & 0 & 0 & \underset{(0.0317)}{-0.0260} & \underset{(0.0377)}{0.0928} & \underset{(0.0338)}{0.0406} \\
0 & 0 & 0 & \underset{(0.0019)}{0.0008} & \underset{(0.0671)}{-0.0544} & \underset{(0.0430)}{0.9451}
\end{bmatrix}
\begin{bmatrix}
(h_{t-1}^{SE})^2 \\
h_{t-1}^{SE,DE} \\
h_{t-1}^{SE,US} \\
h_{t-1}^{DE} \\
h_{t-1}^{DE,US} \\
h_{t-1}^{US}
\end{bmatrix}$$

We have restricted the parameters $\tilde{a}_{ii} + \tilde{b}_{ii}$ to sum to one for i = *SE, US*. The unrestricted estimations suggested that we might adopt these restrictions of integrated processes in the case of the Swedish and

Table 3
Diagnostic tests on the standardised residuals from the BEKK model

Test	Sweden	Germany	United States
Ljung-Box level	22.086 (0.228)	27.421 (0.071)	37.330 (0.005)
Ljung-Box square	18.087 (0.450)	18.248 (0.439)	19.256 (0.376)
Ljung-Box absolute	21.128 (0.273)	9.036 (0.959)	24.245 (0.147)
Skewness	–0.6932 (0.000)	–0.4242 (0.005)	0.0741 (0.622)
Kurtosis	4.7586 (0.000)	4.3696 (0.000)	3.7078 (0.019)
Bera-Jarque	56.207 (0.000)	29.093 (0.000)	5.861 (0.053)

Note: Probability values are in parentheses.

US conditional variances. We will discuss the results in the next section of the paper, but first we take a brief look at some diagnostics.

4.2 Diagnostics

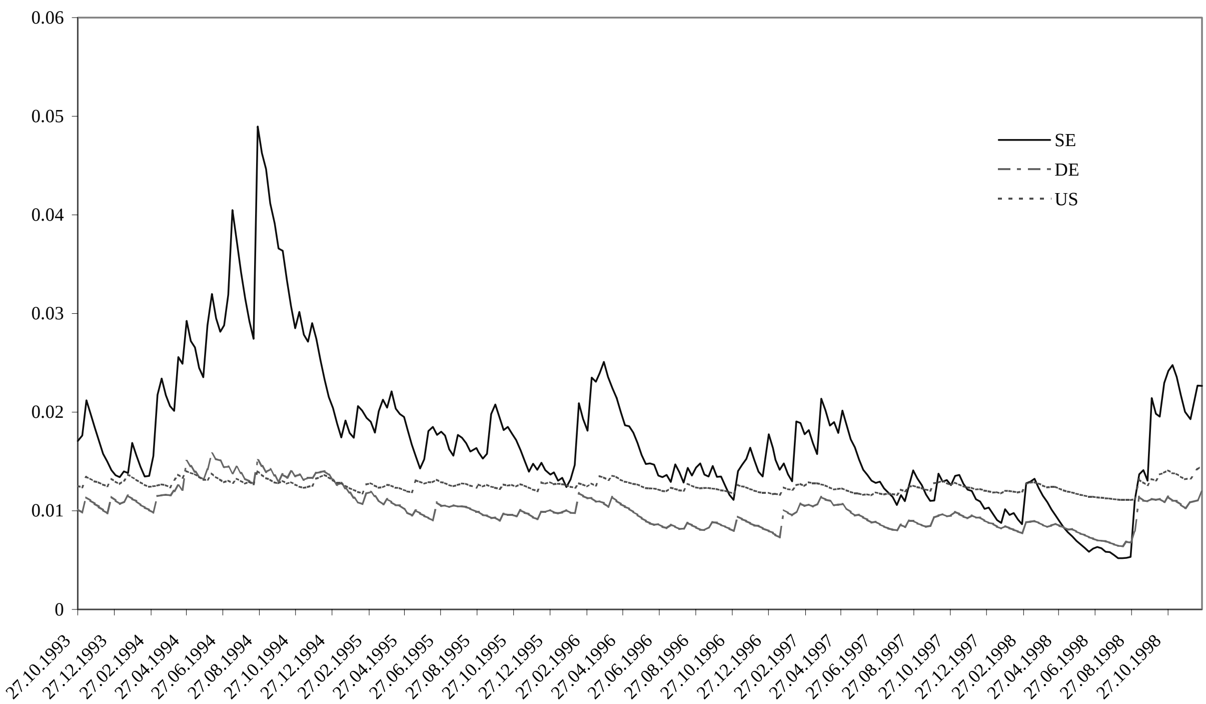
In Table 3, we present some diagnostic tests performed on the standardised residuals from the BEKK model of the previous section. The Ljung-Box tests applied to the residuals (level) show that we have not been entirely successful in allowing for serial correlation. Only the Swedish residuals are satisfactory. However, the same type of test performed on the squared residuals and the absolute value of the residuals does not indicate any remaining heteroscedasticity. The Swedish and German series are skewed and all series are characterised by excess kurtosis.

5. Empirical results

5.1 A characterisation of conditional variances

We have already noted above that there is a high level of persistence in the conditional variances, which even allowed us to restrict the conditional variances of the Swedish and US rates to be integrated GARCH processes. Figure 9 shows the conditional standard deviations in the three markets derived from the BEKK model. How does this analysis compare with the preliminary results presented above? The downward trend in Swedish volatility that we noted in Figure 3a is not as pronounced here. If it were not for the high volatility in 1994, we would be hard pressed to see any trend at all. The analysis of shifts in volatility presented in Section 3 is to a great extent confirmed, but is not in complete agreement with Figure 9. For example, the downward shift found in April 1997 in the German market is not apparent in the figure. In addition, the shift in Swedish volatility in connection with the 1998 crisis was not significant at conventional levels in the breakpoint analysis, while in Figure 9 the Swedish market is the hardest hit of the three. It thus seems that the multivariate model, which models volatility more carefully and takes interactions between the markets into account, gives results somewhat different from the simpler univariate analyses.

Figure 9. Conditional standard deviations



There are two features of the volatility series in Figure 9 that stand out. The first is that the larger the market is, the more stable the conditional standard deviations seem to be. Volatility in the US market is remarkably stable over time. But stable does not necessarily mean lower, since German volatility is actually lower than US volatility (except during 1994). A second interesting feature is that there seems to be a positive comovement between volatility in the three markets. The most dramatic example of this is of course the upward shift in volatility in all three markets during the 1998 crisis. But even during more tranquil times, volatilities seem to move together. We will take a closer look at conditional correlations below.

5.2 Transmission of volatility

Let us now concentrate on the estimated parameters of the $\tilde{A}$ matrix and look for evidence of transmission of volatility shocks between the markets. Somewhat surprisingly, there does not seem to be any transmission of volatility from the German bond market to the smaller Swedish market. The point estimate of $\tilde{a}_{14}$ is positive (0.0045), but the standard error is quite large (0.0267). However, there is evidence of transmission of volatility from the US market to the Swedish and German bond markets. The impact on the Swedish market is greater than on the German market, with point estimates of 0.183 and 0.059 respectively.

Another finding is that shocks to US volatility have a positive impact not only on Swedish and German volatility but also on the conditional covariances between the three markets. German volatility shocks have no significant effect on conditional covariances between the markets, while shocks to Swedish volatility have no effect on the conditional covariances by assumption.

5.3 Conditional correlations

There is a high level of persistence not only in the conditional variances but also in the conditional covariances. The sums of the diagonal parameters, $\tilde{a}_{ii} + \tilde{b}_{ii}$, are all above 0.7. Using the conditional variances and covariances, we have computed the conditional correlations as

Figure 10. Conditional correlations

$$(16) \qquad \rho_t^{ij} = \frac{h_t^{ij}}{\sqrt{h_t^i}\sqrt{h_t^j}}$$

for $i, j \in \{SE, DE, US\}$. These are shown in Figure 10. We can see that the conditional correlation between the two largest markets is the most stable. The correlation between the US and German returns fluctuates within a narrow band around 0.6. It is also the case that the correlation between the Swedish and US markets is more stable than that between the Swedish and German markets. Thus, it seems that the larger the markets considered, the more stable the correlation between them will be. We also note that the Swedish and German markets are more highly correlated than the Swedish and US markets. Both of these correlations fluctuate quite a bit. The correlations with the Swedish market also drop drastically during the 1998 crisis, while the correlation between the US and German markets actually increases.

6. Conclusion

The extent to which interest rates in a small national bond market are determined by domestic relative to foreign factors is of considerable interest from an investment as well as from a monetary policy perspective. We have considered the transmission of shocks from the US and German bond markets to the Swedish market during the recent period of floating exchange rates. We found evidence for the importance of both local and global factors for the small Swedish bond market. We commenced with some preliminary analyses that served to motivate the use of a multivariate GARCH model of the BEKK type. This approach enabled us to model time-varying conditional variances and covariances, which allows a great deal of flexibility in modelling the interaction between the three markets.

Several interesting facts emerged from the estimated multivariate model. The conditional variances in the German and US markets were found to be more stable over time than the conditional variance in the Swedish market. The conditional correlation between the large markets was also found to be quite stable over time, around 0.6, while the Swedish market’s correlations with these two markets were much more volatile (around 0.6 with the German market and 0.4 with the US market). We found no evidence that volatility shocks in the German bond market have any significant impact on the volatility in the Swedish bond market the next week. However, there is clear evidence of transmission of volatility shocks from the US market to the Swedish and German markets from one week to the next. Thus, it appears that news from Germany is more rapidly incorporated into Swedish bond prices than news from the United States.

The more general conclusions that can be drawn from this paper are somewhat tentative because of the limited number of countries investigated. Our main conclusion is that both local and global factors play important roles for a small bond market. We also conclude that larger markets are connected with more stable second moments, that is, conditional variances are more stable, although not necessarily lower, over time in a large market compared with a smaller market. In addition, the larger the markets investigated, the more stable the conditional correlations. It would be of great interest to see how these general conclusions hold up for other sets of countries.

Appendix

Vech representation

Let vec(.) and vech(.) denote the standard vectorisation operators. That is, let L_n denote the elimination matrix, defined so that for a square matrix M, vech(M) = $L_n$vec(M). Furthermore, let D_n denote the duplication matrix, defined so that for any symmetric matrix N, vec(N) = $D_n$vech(N). The dynamics can first be rewritten in vec form as

(17) $$\mathrm{vec}(H_t) = \Omega^* + A^*\mathrm{vec}(\varepsilon_{t-1}\varepsilon'_{t-1}) + B^*\mathrm{vec}(H_{t-1})$$

where $\Omega^* = \mathrm{vec}(\Omega'\Omega)$, $A^* = A' \otimes A'$ and $B^* = B' \otimes B'$. In vech form, the dynamics can then be expressed as

(18) $$\mathrm{vech}(H_t) = \tilde{\Omega} + \tilde{A}\mathrm{vech}(\varepsilon_{t-1}\varepsilon'_{t-1}) + \tilde{B}\mathrm{vech}(H_{t-1})$$

where $\tilde{\Omega} = \mathrm{vech}(\Omega'\Omega)$, $\tilde{A} = L_n A^* D_n = L_n A'_n \otimes A' D_n$ and $\tilde{B} = L_n B^* D_n = L_n B' \otimes B' D_n$.

Bibliography

Baba, Yasunori, Robert F Engle, D F Kraft and Kenneth F Kroner (1990): "Multivariate Simultaneous Generalized ARCH". *Mimeo*, Department of Economics, University of California, San Diego.

Bekaert, Geert and Guojun Wu (1997): "Asymmetric Volatility and Risk in Equity Markets". *Working Paper*, Graduate School of Business, Stanford University.

Bollerslev Tim, Ray Y Chou and Kenneth F Kroner (1992): "ARCH Modeling in Finance: A Review of the Theory and Empirical Evidence". *Journal of Econometrics*, 52, pp. 5-59.

Bollerslev, Tim and Robert F Engle (1993): "Common Persistence in Conditional Variances". *Econometrica*, 61, pp. 167–86.

Bollerslev, Tim, Robert F Engle and Daniel B Nelson (1994): "ARCH Models", in Robert F Engle and Daniel F McFadden (eds.), *Handbook of Econometrics*, Vol. 4, pp. 2951–3038.

Borio, Claudio E V and Robert N McCauley (1996): "The Economics of Recent Bond Market Volatility". *BIS Economic Papers*, No 45.

Davis, E P (1991): "International Diversification of Institutional Investors". Bank of England, Discussion Papers No. 44.

Diebold, Francis X and Marc Nerlove (1989): "The Dynamics of Exchange Rate Volatility: A Multivariate Latent Factor ARCH Model". *Journal of Applied Econometrics*, Vol. 4, pp. 1–21.

Engle, Robert F and Kenneth F Kroner (1995): "Multivariate Simultaneous Generalised ARCH". *Econometric Theory*, Vol. 11, pp. 122-50.

Engle, Robert F, Takatoshi Ito and Wen-Ling Lin (1990): "Meteor Showers or Heat Waves? Heteroskedastic Intra-Daily Volatility in the Foreign Exchange Market". *Econometrica*, Vol. 58, pp. 525–42.

Engle, Robert F and Victor K Ng (1993): "Measuring and Testing the Impact of News on volatility". *Journal of Finance*, Vol. 48, pp. 1749–78.

Engle, Robert F, Victor K Ng, and Michael Rothschild (1990): "Asset Pricing with a Factor – ARCH Covariance Structure: Empirical Estimates for Treasury Bills". *Journal of Econometrics*, Vol. 45, pp. 213–37.

Frankel, Jeffrey A (1992): "Measuring International Capital Mobility". *American Economic Review*, Vol. 82, pp. 197–202.

Glosten, Lawrence R, Ravi Jagannathan and David E Runkle (1993): "On the Relation between the Expected Value and the Volatility of the Nominal Excess Return on Stocks". *Journal of Finance*, Vol. 48, pp. 1779–801.

Hamao, Yasushi, Ronald W Masulis and Victor K Ng (1990): "Correlations in Price Changes and Volatility across International Stock Markets". *Review of Financial Studies*, Vol. 3, pp. 281–307.

Inclán, Carla and George C Tiao (1994): "Use of Cumulative Sums of Squares for Retrospective Detection of Changes of Variance". *Journal of the American Statistical Association*, Vol. 89, pp. 913-23.

King, Mervyn, Enrique Sentana and Sushil Wadhwani (1994): "Volatility and Links between National Stock Markets". *Econometrica*, Vol. 62, pp. 901–33.

Koutmos, Gregory and G Geoffrey Booth (1995): "Asymmetric Volatility Transmission in International Stock Markets". *Journal of International Money and Finance*, Vol. 14, pp. 747-62.

Kroner, Kenneth F and Victor K Ng (1995): "Modeling the Time Varying Co-movements of Asset Returns". *Working Paper*, Wells Fargo Nikko Investment Advisors.

Lin, Wen-Ling, Robert F Engle and Takatoshi Ito (1994): “Do Bulls and Bears Move across Borders? International Transmission of Stock Returns and Volatility”. *Review of Financial Studies*, Vol. 7, pp. 507–38.

Mussa, Michael and Morris Goldstein (1993): “The Integration of World Capital Markets”, in Changing Capital Markets, proceedings of a symposium sponsored by the Federal Reserve Bank of Kansas City.

Nelson, Charles R and Andrew F Siegel (1987): “Parsimonious Modelling of Yield Curves”. *Journal of Business*, Vol. 60, pp. 473–89.

Ng, Victor K, Robert F Engle and Michael Rothschild (1992): “A Multi-Dynamic-Factor Models for Stock Returns”. *Journal of Econometrics*, Vol. 52, pp. 245–66.

Singleton, Kenneth (1994): “Persistence of International Interest Rate Correlations”. Preparation for the Berkeley Program in Finance.

Svensson, Lars E O (1995): “Estimating Forward Interest Rates with the Extended Nelson and Siegel Method”. *Quarterly Review*, Sveriges Riksbank, Vol. 3, pp. 13-26.

Tesar, Linda and Ingrid Werner (1995): “Home Bias and High Turnover”. *Journal of International Money and Finance*, Vol. 14, pp. 467–92.

White, Halbert (1982): “Maximum Likelihood Estimation of Misspecified Models”. *Econometrica*, Vol. 50, pp. 1–26.

The dynamics of international asset price linkages and their effects on German stock and bond markets

Dietrich Domanski and Manfred Kremer[1]

1. Introduction

The financial market turbulences in 1998, as other crises previously, produced strong price movements in the securities markets worldwide. This reflected, first, a general reassessment of credit risk, and, second, a drying-up of liquidity even in some of the largest mature securities markets.[2] As a result, cross-market return correlations temporarily underwent dramatic changes, challenging portfolio allocation and risk management strategies which rely on constant historical comovements of asset prices. Against this background, the immediate question arises of how asset price linkages can be properly measured when they are subject to periodic changes as observed in times of market stress. The main purpose of the present paper is to address this question more thoroughly.

In order to measure the dynamics of international asset price linkages, we first employ bivariate GARCH models to analyse the comovements between weekly stock and bond market returns across the G3 countries. GARCH models take account of the specific time-series properties of short-term asset returns, which is needed to obtain reliable estimates of the cross-country linkages. Next, switching-regime ARCH or "SWARCH" models are applied which can identify different volatility regimes for short-term asset prices endogenously. We use this methodology to address two issues: first, "Are international short-term return linkages state-dependent?", and second, "Do volatility spillovers affect individual segments of the domestic bond or stock market differently (i.e. are they market-segment-dependent)?" The first question may also be referred to as the "contagion hypothesis". This states that contagion leads to a significant increase in the cross-market correlation during states of financial market turmoil. Hence, contagion differs from mere "interdependence" in that it demands a stronger-than-normal market linkage during periods of stress.[3]

The paper is organised as follows: Section 2 presents some stylised facts on short-term asset returns derived from summary statistics and simple cross-market correlations. In the third section, we outline the ARCH and SWARCH techniques employed to assess the comovements of weekly returns on various bond and stock price indices. In Section 4, the hypothesis of state-dependent international volatility spillovers between the United States, Japan and Germany is tested. The fifth section examines the question of market-segment-dependent contagion within the German financial system. Section 6 concludes by addressing some possible implications of the results.

2. Measuring international asset price linkages: some stylised facts

The asset universe considered in this paper comprises G3 bond and stock markets, the former represented by the prices of 10-year benchmark government bonds, the latter by broad-market price indices of Datastream (DS country indices).[4] Additionally, the following segments of German

---

1 The views expressed in this paper are those of the authors and do not necessarily reflect the opinion of the Deutsche Bundesbank.

2 See International Monetary Fund (1998), p. 38.

3 See Forbes and Rigobon (1999), p. 1, and Baig and Goldfajn (1999), p. 169.

4 A detailed description of the data is given in the Appendix.

financial markets are analysed: in the bond market, different maturities for benchmark government bonds (besides the 10-year maturity, also two, five and seven years), as well as the price index for 10-year Pfandbriefe ("PEX") are considered. The stock market is broken down into the blue chips contained in the DAX, and a segment for medium-sized and small stocks, respectively (MDAX and SMAX).[5] Asset price movements are measured as weekly returns, based on Thursday figures for Germany and Japan. For the United States, Wednesday figures are used, taking into account the asynchrony between these markets with the US market performing a lead function for the others.[6] The stock market data cover the period from January 1980 (MDAX and SMAX: October 1988) until September 1999. The bond market sample ranges from January 1984 (PEX: January 1988) to September 1999.

Table A1 in the Appendix shows some univariate summary statistics for all time series of weekly asset returns analysed in this paper. Over the entire sample period, stock markets generate higher, less autocorrelated and more volatile returns than bond markets do. Despite these marked differences, both asset classes share many other features typical of higher-frequency asset prices. First, returns exhibit substantial non-normality (as can be seen from the Jarque-Bera statistic) which mainly stems from excess kurtosis. That is, the distributions of short-term returns are characterised more by fat tails than by asymmetry (skewness). Moreover, autocorrelation is generally low and often insignificant. Finally, ARCH tests reveal strong volatility clustering in bond and stock returns. These properties suggest using a time-series framework for modelling short-term asset returns which captures serial correlation in the conditional means and variances, and which generates unconditionally leptokurtic, but not necessarily skewed returns.

Table 1
Cross-correlation matrix of weekly returns on different stock and bond markets

Stock market (below diagonal: 1988/10/6 to 1999/9/16; above diagonal: 1980/1/10 to 1999/9/16)

	DS US	DS JP	DS DE	DAX	MDAX	SMAX
DS United States	–	**0.38**	**0.49**	n. c.	n. a.	n. a.
DS Japan	**0.34**	–	**0.32**	n. c.	n. a.	n. a.
DS Germany	**0.55**	**0.33**	–	n. c.	n. a.	n. a.
DAX	0.54	0.32	0.99	–	n. a.	n. a.
MDAX	0.47	0.31	0.88	0.82	–	n. a.
SMAX	0.42	0.29	0.69	0.63	0.77	–

Bond market (below diagonal: 1988/1/7 to 1999/9/16; above diagonal: 1984/1/12 to 1999/9/16)

	10-yr US	10-yr JP	10-yr DE	7-yr DE	5-yr DE	2-yr DE	10-yr PEX
10-yr United States	–	**0.22**	**0.47**	n. c.	n. c.	n. c.	n. a.
10-yr Japan	**0.23**	–	**0.28**	n. c.	n. c.	n. c.	n. a.
10-yr Germany	**0.48**	**0.22**	–	n. c.	n. c.	n. c.	n. a.
7-yr Germany	0.45	0.22	0.94	–	n. c.	n. c.	n. a.
5-yr Germany	0.37	0.19	0.86	0.92	–	n. c.	n. a.
2-yr Germany	0.24	0.17	0.65	0.76	0.82	–	n. a.
10-yr PEX	0.43	0.18	0.88	0.91	0.85	0.70	–

Note: The sample for the correlation coefficients in the lower triangular parts is restricted by the start date of the shortest stock market and bond market price index, respectively. The cross correlations above the diagonal are only calculated for the representative price indices of each country. – n. c.: not calculated; n. a.: not available.

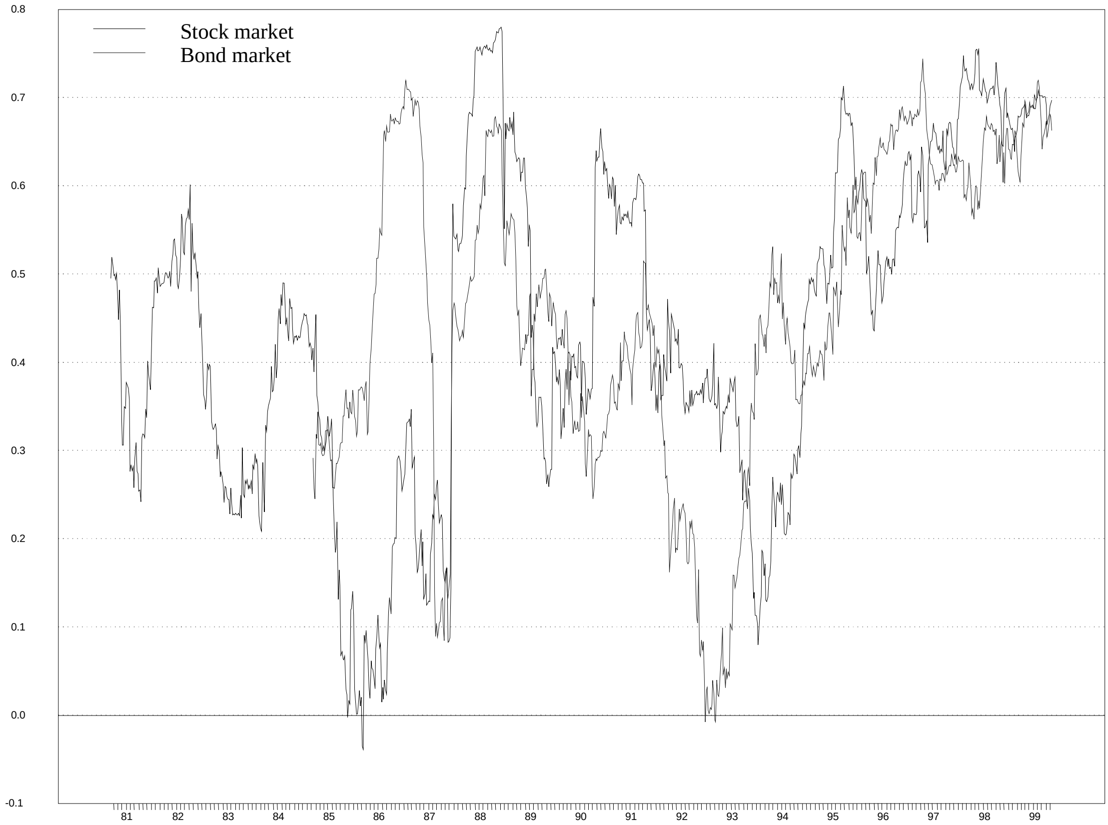
5 Some information about the structure of these market segments is provided in Section 5.

6 This lead property of the US bond and equity market is confirmed by the lead and lag structure of correlations between daily price changes with other markets. Returns in both the German and the Japanese markets exhibit the highest correlation for a one-day lead of the US market; contemporaneous correlations are only about half as high as this lead.

Longer-term cross-market linkages are usually measured by the simple correlation coefficient between asset returns over a certain sample period. Table 1 displays cross-correlation coefficients for the stock and bond markets under study. The average stock and bond market linkages measured in this way are much stronger between the United States and Germany than they are between Japan and either the United States or Germany. Furthermore, international linkages seem to be somewhat closer across stock markets than across bond markets. Regarding German market segments, the almost identical correlation structure of the DAX and the German DS index proves that the latter – being a broad value-weighted index – is, in fact, dominated by the prices of blue chip titles. The correlation of the DS index then decreases with the aggregate size of the stocks included in the MDAX and the SMAX, respectively. The correlation pattern between German government bond segments suggests that the "substitutability" of bonds decreases as the maturity difference becomes larger.

Figure 1: Moving cross-country return correlation on stock and bond markets

Germany vs the United States; moving 52-week window



To assess possible time-variation or structural breaks, the correlation is often calculated over either non-overlapping sub-periods or a moving window.[7] As an example, moving 52-week correlations between German and US returns on bonds and stocks, respectively, are shown in Figure 1. It demonstrates how strongly moving correlations can change over time. However, the marked ups and downs may only reflect the strong influence of single large price shocks on such "short-memory" correlations. This sensitivity renders a structural interpretation of this measure of international asset price linkages rather doubtful.

---

7 See, for example, Deutsche Bundesbank (1997), p. 30 f.

3. The methodological framework: ARCH and SWARCH models

In order to measure and model international asset price linkages more reliably, an econometric modelling technique should be applied which takes into account the specific time-series properties of short-run asset returns (and which should be less sensitive to single price shocks). Most importantly, the strong volatility clustering in weekly stock and bond market returns as well as their unconditional non-normality have to be modeled. For this purpose, ARCH-type models (AutoRegressive Conditional Heteroskedasticity) have become a widely applied tool.[8] They can be specified very flexibly according to the specific data needs, which has led to the development of a wide variety of types.[9] We shall begin with a bivariate AR(1)-GARCH(1,1) specification for each pair of either stock or bond returns. In most cases such a parsimonious specification suffices. First, the near-unpredictability of short-run asset returns allows us to restrict the forecast equations for the conditional means to simple AR(1) processes.[10] Second, while the volatility of returns contains substantial predictability, most of its dynamics can usually be captured by a low-order GARCH system.

The AR(1) part describes the conditional means as:

$$(1) \qquad r_{j,t} = \mu_{j,t} + \varepsilon_{j,t} \quad \text{with} \quad \mu_{j,t} = E_t\left[r_{j,t} | \Omega_{t-1}\right] = \alpha_j + \beta_j r_{j,t-1} \quad \text{for } j = \text{asset } x, \text{asset } y$$

where $r_{j,t}$ denotes the weekly return of asset j, $\mu_{j,t}$ for the expected return conditional on information Ω_{t-1} (in a linear projection), and $\varepsilon_{j,t}$ a random error. The error vector ε_t is assumed to follow a bivariate normal distribution, with zero mean and a time-varying covariance matrix H_t:

$$(2) \qquad \varepsilon_t | \Omega_{t-1} \sim N(0, H_t)$$

The system is completed by three equations which describe the dynamics of the distinct elements of H_t. Because of the symmetry of H_t , this subsystem can be summarised with the "vech representation" of our bivariate GARCH(1,1) model:[11]

$$(3) \qquad \begin{bmatrix} h_{x,t} \\ h_{xy,t} \\ h_{y,t} \end{bmatrix} = \begin{bmatrix} c_{11} \\ c_{12} \\ c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} \varepsilon^2_{x,t-1} \\ \varepsilon_{x,t-1}\varepsilon_{y,t-1} \\ \varepsilon^2_{y,t-1} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} h_{x,t-1} \\ h_{xy,t-1} \\ h_{y,t-1} \end{bmatrix}$$

with $h_{j,t}$ the conditional error variance of the return of asset j, and $h_{xy,t}$ the conditional covariance. In this unrestricted system, international "volatility transmission" can occur through a variety of mechanisms. For example, the variance $h_{x,t}$ depends – via the parameters a_{12}, a_{13}, $b_{12}$and b_{13} – directly on the lagged residuals and lagged variance of asset y. Moreover, there is also a mutual contemporaneous dependency which comes through the covariance function $h_{xy,t}$. In effect, this function determines the expected comovement between asset returns, although the causal direction of this interrelationship is not identified a priori.[12] We can estimate the degree of comovement dimension-free by the time-varying (conditional) correlation coefficient:

---

8 For a review of the theory and broad empirical evidence, see Bollerslev et al. (1992).

9 See Bollerslev et al. (1992) or Bera and Higgins (1993).

10 See Cochrane (1999), p. 37. The same does not generally hold for long-run returns, which is often partially predictable. For a discussion of this issue and some recent evidence, see, for example, Campbell et al. (1998), Chapter 2, and Domanski and Kremer (1998, 1999).

11 The general form of the vech representation is:

$$vech(H_t) = vech(C) + \sum_{i=1}^{q} A_i vech(\varepsilon_{t-i}\varepsilon'_{t-i}) + \sum_{j=1}^{p} B_j vech(H_{t-j}) \,.$$

The *vech* operator stacks all elements on and below the main diagonal of an $n \times n$ symmetric matrix column by column into an $n(n+1)/2$-dimensional vector. The coefficient matrices A and B are accordingly of dimension $n(n+1)/2 \times n(n+1)/2$).

12 To determine causality, one would have to impose identifying restrictions on the variance covariance matrix which would make the residuals orthogonal as in many structural VAR representations.

(4) $\rho_t = h_{xy,t}/(h_{x,t}\, h_{y,t})^{0.5}$

This measure should be superior to the simple correlations as used in Section 2 since it is estimated within a consistent econometric framework. Nevertheless, estimating the full vech representation faces two serious drawbacks. First, positive definiteness of the variance covariance matrix is not guaranteed. Second, the system is heavily overparameterised (bivariate GARCH(1,1) models require 21 coefficients to be estimated for the variance covariance process alone). To mitigate these problems, two restricted representations are applied: first, we impose zero-restrictions on all elements below and above the main diagonal of the coefficient matrices *A* and *B*. This “diagonal representation” suggested by Bollerslev et al. (1988) reduces the estimating burden to nine parameters. The conditional variance processes equal those of univariate GARCH models since neither squared lagged residuals nor the lagged variance of one variable appear in the variance equation of the other. Hence, the international volatility transmission can now occur only through the conditional covariance process. The diagonal representation of the bivariate base model (with some convenient changes in notation) looks as follows:

$$(5) \qquad \begin{bmatrix} h_{x,t} \\ h_{xy,t} \\ h_{y,t} \end{bmatrix} = \begin{bmatrix} c_x \\ c_{xy} \\ c_y \end{bmatrix} + \begin{bmatrix} a_x & 0 & 0 \\ 0 & a_{xy} & 0 \\ 0 & 0 & a_y \end{bmatrix} \begin{bmatrix} \varepsilon^2_{x,t-1} \\ \varepsilon_{x,t-1}\varepsilon_{y,t-1} \\ \varepsilon^2_{y,t-1} \end{bmatrix} + \begin{bmatrix} b_x & 0 & 0 \\ 0 & b_{xy} & 0 \\ 0 & 0 & b_y \end{bmatrix} \begin{bmatrix} h_{x,t-1} \\ h_{xy,t-1} \\ h_{y,t-1} \end{bmatrix}$$

Second, the model can be further simplified by assuming a constant correlation coefficient $\rho_t = \rho$ as proposed by Bollerslev (1990). In this case, the conditional covariance function degenerates to the identity:

(6) $h_{xy,t} = \rho\,(h_{x,t}\, h_{y,t})^{0.5}$

Together with the two unchanged conditional variance processes, it forms the “constant correlation representation” which leaves seven parameters to be estimated.[13] Positive definiteness of the variance covariance matrix can now be guaranteed. Despite its restrictive nature (it does not permit any lagged international volatility spillovers), the constant correlation representation renders it quite useful. First, it provides a simple summary measure of international asset price linkages, immediately challenging the simple return correlation. Second, it offers an easy way of directly testing specific hypotheses about possible determinants and the structural stability of the correlation coefficient. Concerning its presumed dependence on volatility regimes, the parsimony of the constant correlation representation makes it a natural candidate for multivariate switching-regime ARCH (SWARCH) models which multiply the number of parameters to be estimated.[14]

However, since multivariate SWARCH models soon become intractable when more than two or three endogenous variables are involved, the present paper confines itself to univariate SWARCH models which are used to identify volatility regimes in certain asset returns. SWARCH models date back to the independent work of Cai (1994) and Hamilton and Susmel (1994). This model class allows conditional volatility to be both time- and state-variant while the volatility regimes are identified and estimated endogenously. The appropriate number of states remains an empirical question and can be tested statistically. We further the hypothesis of two states, i.e. periods of high and low volatility. In the univariate case, the variance equation when allowing for two different states S_t = 1 or 2 is given by:[15]

---

[13] The BEKK representation, as another variant of multivariate GARCH models, works without (a priori) imposing zero-restrictions upon the off-diagonal elements of the matrices *A* and *B*. Instead, it uses non-linear cross-equation restrictions to reduce the estimating burden. A recent application to bond rates for the G3 countries is Herwartz and Reimers (1999).

[14] Ramchand and Susmel (1998) successfully applied univariate and bivariate SWARCH models to assess regime-dependent cross correlations between weekly stock returns of a broad set of countries.

[15] To save degrees of freedom, the AR(1) model for the mean return equation 1 remains state-independent as is the case in related work. This assumption is not very restrictive due to the near-unpredictability of weekly returns.

(7) $$h_{S_t,t} = c_{S_t} + a_{S_t}\varepsilon_{t-1}^2 + b_{S_t}h_{t-1} \qquad \text{for } S_t = 1, 2$$

This specification follows the “generalised regime switching” (GRS) model of Gray (1996) and differs from the models of Cai and Hamilton and Susmel. The original SWARCH models were restricted to low-order ARCH processes because they assumed that regime-switching GARCH models would be “intractable and impossible to estimate due to the dependence of the conditional variance on the entire past history of the data in a GARCH model”.[16] Gray (1996) solved the problem of path dependence by recognising that the conditional density of the endogenous variable is essentially a mixture of distributions with time-varying mixing parameters. If conditional normality is assumed within each regime, the variance at time *t* can be calculated, in our case very simply, as:

(8) $$\begin{aligned} h_t &= E[r_t^2|\Omega_{t-1}] - E[r_t\,|\Omega_{t-1}]^2 \\ &= p_{1,t}h_{1,t} + (1-p_{1,t})h_{2,t} \end{aligned}$$

where $p_{1,t} = \text{Prob}\left[S_t = 1|\Omega_{t-1}\right]$ denotes the conditional probability at time *t* of being in state 1 given information at time *t*-1.[17] Now h_t, which is not path-dependent, can be used as the lagged conditional variance in constructing $h_{1,t+1}$ and $h_{2,t+1}$ as described in equation 7. However, the main feature of Markov switching models is the parameterisation of the probability law that causes the unobserved (latent) regime indicator S_t to switch among regimes.[18, 19] In this study, we focus on the simplest case of a two-state, first-order Markov process (where S_t only depends on the state of the previous period) with constant “transition probabilities”:

(9) $$\text{Prob}\left[S_t = j|S_{t-1} = i, \Omega_{t-1}\right] = \text{Prob}\left[S_t = j|S_{t-1} = i\right] = p_{ij} \qquad \text{for } i = 1, 2 \text{ and } j = 1, 2$$

The probability p_{ij} gives the probability that state *i* will be followed by state *j*. However, since the restriction:

(10) $$p_{i1} + p_{i2} = 1 \qquad \text{for } i = 1, 2$$

applies, only two of these four probabilities can be determined independently. We focus on the regime probabilities p_{11} and p_{22} and substitute out the switching probabilities p_{12} and p_{21} by using (10). Since the conditional probability $p_{1,t}$ only depends on the regime the process is in at time *t*-1, it can be expressed as:

(11) $$\begin{aligned} \text{Prob}\left[S_t = 1|\Omega_{t-1}\right] &= \sum_{i=1}^{2} \text{Prob}\left[S_t = 1|S_{t-1} = i, \Omega_{t-1}\right]\text{Prob}\left[S_{t-1} = i|\Omega_{t-1}\right] \\ &= p_{11}\,\text{Prob}\left[S_{t-1} = 1|\Omega_{t-1}\right] + (1-p_{22})\,\text{Prob}\left[S_{t-1} = 2|\Omega_{t-1}\right] \end{aligned}$$

The $\text{Prob}\left[S_{t-1} = i|\Omega_{t-1}\right]$ can be obtained by updating the probabilities $\text{Prob}\left[S_{t-1} = i|\Omega_{t-2}\right]$ using the incoming information r_{t-1} (since $\Omega_{t-1} = \{r_{t-1}, \Omega_{t-2}\}$ in our case) according to Bayes’ Rule:

(12) $$\begin{aligned} \text{Prob}\left[S_{t-1} = i|\Omega_{t-1}\right] &= \text{Prob}\left[S_{t-1} = i|r_{t-1}, \Omega_{t-2}\right] \\ &= \frac{f(r_{t-1}|S_{t-1} = i, \Omega_{t-2})\text{Prob}\left[S_{t-1} = i|\Omega_{t-2}\right]}{\sum_{i=1}^{2} f(r_{t-1}|S_{t-1} = i, \Omega_{t-2})\text{Prob}\left[S_{t-1} = i|\Omega_{t-2}\right]} \end{aligned}$$

---

16 Gray (1996), p. 34.

17 See equation 8 in Gray (1996), p. 34.

18 Markov switching models owe their name to the assumption that S_t depends upon S_{t-1}, S_{t-2}, ..., S_{t-r}, in which case the stochastic process of S_t is named as an *r*-th order (in general *K*-state) Markov chain.

19 If the whole path of S_t is known a priori, the estimation problem would be reduced to that of a simple GARCH model with shift and interactive dummy variables that take account of the different regimes (Kim and Nelson (1999), p. 60).

where:

$$f(r_{t-1}|\mathrm{S}_{\text{t-1}}=i,\Omega_{t-2}) = f(r_{t-1}|\mathrm{S}_{\text{t-1}}=i)$$

(13)
$$= \frac{1}{\sqrt{2\pi h_{i,t-1}}}\exp\left\{\frac{-(r_{t-1}-\alpha-\beta r_{t-2})^2}{2h_{i,t-1}}\right\}$$

is the density of the conditionally normally distributed returns variable r_{t-1} conditional on a given state i. Combining (11) and (12) provides a relatively simple non-linear recursive scheme for the "filtered probability" of regime 1:[20]

(14)
$$p_{1,t} = p_{11}\left[\frac{f(r_{t-1}|S_{t-1}=1)\,p_{1,t-1}}{f(r_{t-1}|S_{t-1}=1)\,p_{1,t-1}+f(r_{t-1}|S_{t-1}=2)(1-p_{1,t-1})}\right]$$
$$+(1-p_{22})\left[\frac{f(r_{t-1}|S_{t-1}=2)(1-p_{1,t-1})}{f(r_{t-1}|S_{t-1}=1)\,p_{1,t-1}+f(r_{t-1}|S_{t-1}=2)(1-p_{1,t-1})}\right]$$

The log-likelihood function log L can then be written as:

(15)
$$\log L = \sum_{t=1}^{T}\log\left[p_{1,t}\,f(r_t|S_t=1)+(1-p_{1,t})\,f(r_t|S_t=2)\right]$$

Hence, it also possesses a recursive structure similar to the log likelihood of conventional GARCH models. The function can be maximised with respect to p_{11}, p_{22}, α, β, c_1, c_2, a_1, a_2, b_1, b_2 after choosing appropriate starting values.[21]

All GARCH and SWARCH models in this paper were estimated by maximising the respective log-likelihood functions numerically using the RATS instruction MAXIMIZE with the BFGS algorithm. We always maintained the assumption of normally distributed errors, although in many cases the standardised residuals, while otherwise quite well-behaved, still showed a substantial degree of excess kurtosis. Even under this condition, maximisation of the log-likelihood function should still yield reasonable parameter estimates. This procedure is described as pseudo or quasi-Maximum Likelihood (QML).[22] But since the standard errors are likely to be severely biased, we computed them from the heteroskedasticity-consistent variance covariance matrix as proposed by White (1982).

4. International correlation of asset price movements: does market turbulence matter?

The empirical analysis starts with an estimation of the constant correlation representation of bivariate AR(1)-GARCH(1,1) models as the most restricted specification. Following this "base model", we estimate the diagonal representation, which delivers a time-varying correlation coefficient as described in equation 4. This allows us to obtain a first visual impression about the dynamics of international asset price linkages. However, to test hypotheses about the driving factors behind these dynamics, the constant correlation representation is more often used in the literature because of its ease and

---

[20] The literature makes a distinction between "filtered probabilities" and "smoothed probabilities". The smoothed probabilities use all information available for the entire sample $t = 1,...,T$ to make inferences about the state prevailing at each date t. They are thus more ex post in character. The filtered probabilities, by contrast, use only information up to the respective forecast origin and are therefore more ex ante-oriented. See Kim and Nelson (1999), chapter 4, for details.

[21] In fact, to ensure that the estimated transition probabilities p_{11} and p_{22} lie in the interval (0, 1), they are constrained by the transformation $p_{ii} = \exp\{\pi_{ii}\}/(1+\exp\{\pi_{ii}\})$. The numerical optimisation is then applied with respect to the unconstrained π_{ii}.

[22] See, for example, Hamilton (1994), p. 145.

tractability. Within the present context, it allows the correlation coefficient to be modelled as a function of different economic states.[23] For example, Longin and Solnik (1995) test whether the correlation changes with a priori defined variance regimes (smooth versus turbulent periods) which enter the model as shift dummies in the correlation function. As a methodology that does not rely on a priori defined regimes, we apply parsimonious SWARCH models to identify different volatility states endogenously and to see whether simple return correlations change with the regimes.

4.1 Correlation across major stock markets

Table 2 reports the results of the bivariate GARCH models for each pair of the US, German and Japanese weekly stock returns. There are some general results which hold for each pair of countries irrespective of the model's representation. As is to be expected, stock returns are materially unpredictable on the basis of the past week's returns as indicated by the β coefficients, with the result that the constants α in the conditional mean equations roughly equal the respective sample means as shown in Table 1.[24] The variance equations all look reasonable and are in line with results generally found in the literature using higher-frequency financial data. The conditional variances are highly persistent as judged by the sum of the autoregressive coefficients ($a_j + b_j$), which in all cases never reaches, but still comes close to, one.[25] Most of the persistence derives from the lagged variance rather than the lagged squared residuals, which tends to smooth out the conditional variance process somewhat. The last three lines of Table 2 show the unconditional moments of the variance covariance matrix. The unconditional variances also appear reasonable except for two of the three Japanese equations. In these two cases, the implied steady-state volatilities (with 8.89 and 9.13) seem to be biased upwards when compared with the ordinary sample variance (5.86).[26]

The correlation coefficients are very precisely estimated with the constant correlation representation. Furthermore, they do not differ much from the unconditional sample moments except in the German-Japanese case, where they are considerably lower. This result changes somewhat under the diagonal representation. The implied unconditional correlation is much higher in the US-German case but lower for both the US-Japanese and the German-Japanese case. However, these results may be overstated since the constants in the three conditional covariance equations – and thus the unconditional moments, too – are rather imprecisely estimated and may therefore contain a substantial bias.

We now turn to the dynamics as implied by the time-varying correlation coefficient from the diagonal GARCH representation as defined in equation 4. Figure 2 shows the time series of this correlation for the US-German case and the US-Japanese case respectively (solid line). The dashed line marks the correlation as estimated by the constant correlation representation. For one thing, the US-Japanese correlation is more variable than the US-German correlation. For another, the first seems to revert rather quickly to its "mean" value over the entire sample, while the latter remains for quite a long time either below or above its supposed attractor level. Furthermore, the visual inspection might suggest that the US-German correlation has been following a moderate upward trend at least since 1993 (or even since 1988). However, we were unable to confirm this hypothesis statistically.[27]

---

[23] Alternatively, the correlation could also be modelled as a function of deterministic time trends or of any information variable. Recent related studies which have applied this framework are Longin and Solnik (1995) and Bodart and Reding (1999).

[24] This picture does not change when estimating first-order VAR(1)-GARCH(1,1) models that add the other country's lagged return to the explanatory variables.

[25] The approximate unit root in the autoregressive polynomial questions the stationarity of the conditional variance process and has led to the development of so-called IGARCH models (integrated in variance). See Bollerslev et al. (1992), p. 14f.

[26] The unconditional variance, for example, can be calculated as $c_j/(1 - a_j - b_j)$ by applying the law of iterated expectations. See Bera and Higgins (1993), p. 314.

[27] We tried deterministic trend variables – beginning in either 1988 or 1993 – as an explanatory variable in a linear function for the correlation coefficient in the constant correlation representation. However, the estimated coefficients were highly insignificant in both cases. We also tested for secular trends in correlation over the whole sample, but this test also failed.

Table 2

Bivariate AR(1)-GARCH(1,1) models for major stock markets

(1) $r_{j,t} = \alpha_j + \beta_j r_{j,t-1} + \varepsilon_{j,t}$ for $j = x, y$ (country x vs country y)

(5a) $h_{j,t} = c_j + a_j \varepsilon^2_{j,t-1} + b_j h_{j,t-1}$

(6) $h_{xy,t} = \rho(h_{x,t-1} h_{y,t-1})^{0.5}$ constant correlation representation

(5b) $h_{xy,t} = c_{xy} + a_{xy} \varepsilon_{x,t-1} \varepsilon_{y,t-1} + b_{xy} h_{xy,t-1}$ diagonal representation

	Constant correlation representation						**Diagonal representation**					
	US vs DE		US vs JP		DE vs JP		US vs DE		US vs JP		DE vs JP	
α_x	0.267	(0.057)[2]	0.297	(0.055)[2]	0.263	(0.062)[2]	0.286	(0.058)[2]	0.303	(0.051)[2]	0.274	(0.065)[2]
β_x	–0.035	(0.031)	–0.042	(0.034)	0.044	(0.035)	–0.046	(0.032)	–0.039	(0.029)	0.049	(0.036)
α_y	0.249	(0.057)[2]	0.249	(0.053)[2]	0.235	(0.051)[2]	0.244	(0.047)[2]	0.245	(0.055)[2]	0.249	(0.059)[2]
β_y	0.030	(0.030)	0.039	(0.031)	0.043	(0.034)	0.037	(0.028)	0.048	(0.030)	0.031	(0.032)
c_x	0.245	(0.153)	0.250	(0.229)	0.351	(0.133)[2]	0.232	(0.135)	0.208	(0.106)[1]	0.387	(0.165)[1]
c_y	0.367	(0.115)[2]	0.143	(0.062)[1]	0.130	(0.070)	0.351	(0.156)[1]	0.155	(0.070)[2]	0.175	(0.069)[1]
c_{xy}	–	–	–	–	–	–	0.126	(0.076)	0.104	(0.054)	0.209	(0.123)
a_x	0.099	(0.041)[1]	0.098	(0.056)	0.170	(0.046)[2]	0.088	(0.036)[1]	0.087	(0.029)[2]	0.165	(0.051)[2]
a_y	0.161	(0.038)[2]	0.141	(0.030)[2]	0.136	(0.029)[2]	0.148	(0.047)[1]	0.154	(0.028)[2]	0.133	(0.024)[2]
a_{xy}	–	–	–	–	–	–	0.087	(0.037)[1]	0.115	(0.026)[2]	0.129	(0.051)[1]
b_x	0.845	(0.064)[2]	0.845	(0.098)[2]	0.758	(0.057)[2]	0.858	(0.053)[2]	0.865	(0.042)[2]	0.752	(0.069)[2]
b_y	0.761	(0.045)[2]	0.842	(0.033)[2]	0.849	(0.032)[2]	0.776	(0.066)[2]	0.829	(0.032)[2]	0.842	(0.028)[2]
b_{xy}	–	–	–	–	–	–	0.846	(0.065)[2]	0.813	(0.061)[2]	0.679	(0.148)[2]
ρ	**0.457**	(0.019)[2]	**0.352**	(0.028)[2]	**0.273**	(0.033)[2]	–	–	–	–	–	–
h_x^*	4.395	–	4.374	–	4.878	–	4.280	–	4.392	–	4.680	–
h_y^*	4.692	–	8.575	–	8.890	–	4.597	–	9.126	–	6.798	–
ρ^*	–	–	–	–	–	–	**0.578**	–	**0.227**	–	**0.194**	–

Note: The table gives the estimated coefficients calculated by Maximum Likelihood using the BFGS algorithm. Heteroskedasticity-consistent standard errors in parentheses. Effective sample: 24 January 1980 to 16 September 1999 (1,026 usable observations). [1] [(2)] indicates significance at the 5% (1%) level. h_i^* is the unconditional variance of country j's unexpected return, and ρ^* is the unconditional correlation coefficient, both calculated as the steady-state solutions to the variance and covariance equations 5a and 5b and using the definition of the correlation coefficient.

It is often argued that international stock market correlations increase in periods of stress with high conditional return volatilities. Figure A1 in the Appendix gives a visual impression of why this hypothesis is raised so often. The conditional variance series for both the United States and Germany are shown in the lower part, while the corresponding correlation coefficient appears in the upper part. Obviously, the correlation jumps upwards when both markets are hit by large shocks, as in October 1987 and August 1990. Empirical evidence in favour of this hypothesis is provided, for instance, by Koch and Koch (1991), and Longin and Solnik (1995). However, these studies did not find a statistically fully convincing solution to the problem of separating volatility regimes. Lacking a proper methodology, they had to define the sub-periods of high versus low volatilities exogenously in an ad hoc fashion. SWARCH models now provide a technology for doing this job endogenously. They were first applied in this context by Ramchand and Susmel (1998), who find strong evidence for state-dependent correlations across weekly stock returns for a large set of countries.

This result does not necessarily contradict the findings in Longin and Solnik (1995), who used a much larger sample (1960 to 1990) with monthly stock returns for their bivariate GARCH models.

Figure 2: International stock return correlations from bivariate GARCH models

Constant correlation representation (dashed) and diagonal representation (solid)

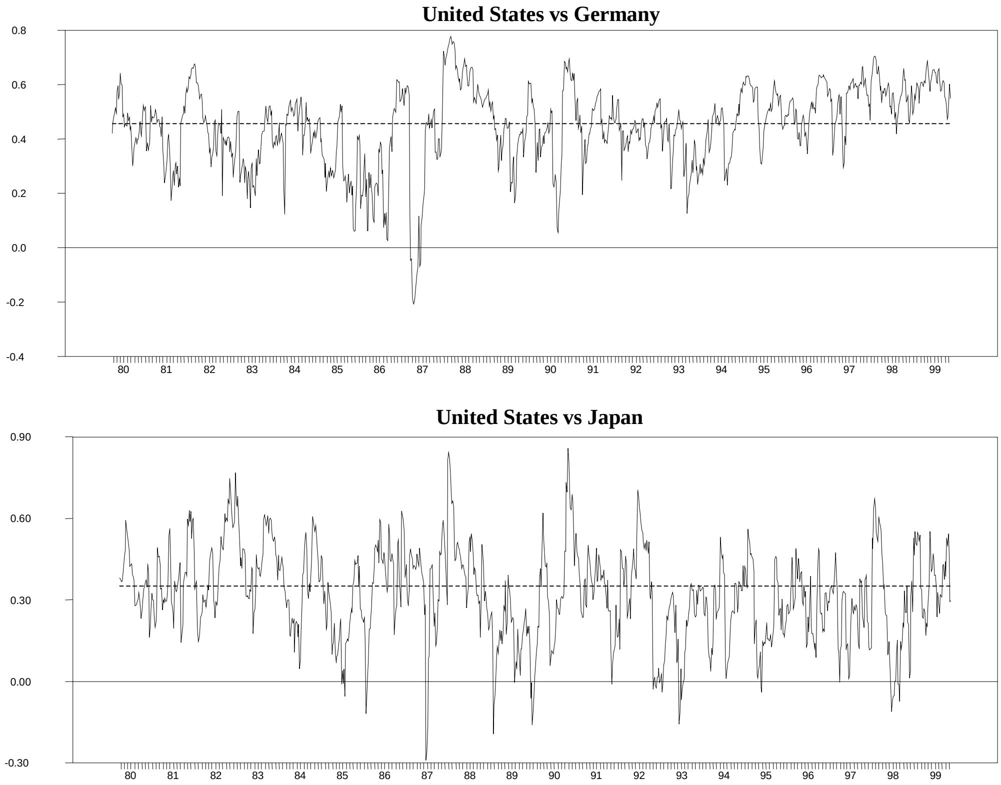


Table 3 presents our results of univariate SWARCH specifications. The model produces similar estimates for all of the stock returns. Most noticeable are the clear-cut and highly significant differences in the two identified, country-specific variance regimes.[28] The unconditional variances of the high volatility state are three to five times larger than those of the low volatility state. Moreover, the use of the generalised regime-switching model specification of Gray (1996) proves to be advantageous since it allows the persistence parameter a_{St} to differ between regimes in contrast to the original SWARCH specifications. Within the low volatility state, the variances remain virtually constant due to the negligible (and insignificant) autoregression coefficients a_1. In the high volatility state, however, lagged squared residuals do have a significant and materially important influence on current conditional variances via parameters a_2. This makes large initial shocks, as typically observed in market crashes, persist for some time.

Furthermore, each regime itself is highly persistent as evidenced by the large (and, in general, highly significant) constant regime probabilities p_{11} and p_{22}, respectively.[29] This result is consistent with applications of Markov switching in many other contexts. Accordingly, the time series for the conditional regime probabilities look quite reasonable. As an example, Figure 3 presents the conditional probability of German stock returns being in state 1 ($p_{1,t}$), the low variance regime. This

[28] We have to admit that individual standard errors of the parameters of the state-dependent variance equations do only provide an informal test of the two-state model against a simple one-state specification, since under the null hypothesis of no-regime switching the parameters of the second state's variance equation are not identified. However, we regard the evidence in favour of the two-state model as so strong that we dispensed with a proper non-standard test such as that developed by Hansen (1992).

[29] Table 3 does not show standard errors for the "constrained" transition probabilities since standard errors were only obtained for the unconstrained probability parameters which are not directly interpretable and thus not shown in the table.

probability is (i) either near one or close to zero, and this (ii) for extended periods of time. The second quality reflects the high regime (or low transition) probabilities. The first property indicates the good performance of the conditional probability in classifying volatility regimes since, being close to its boundaries, it provides a clear signal as to whether a given observation belongs to a certain regime or not. This quality can be measured statistically by the Regime Classification Measure (RCM) proposed by Ang and Bekaert (1998). The RCMs for the SWARCH models of German, Japanese and US returns lie between 35 and 55 (see Table 3). Being so low, the RCMs prove our visual impression that the regime inference of the SWARCH models is generally strong and, hence, quite reliable.[30]

Table 3
Univariate SWARCH(2,1) models for major stock markets

(1) $r_t = \alpha + \beta r_{t-1} + \varepsilon_t$

(7) $h_{S_t,t} = c_{S_t} + a_{S_t}\varepsilon_{t-1}^2$ for $S_t = 1, 2$

(9) $p_{ij} = \mathrm{Prob}\left[\mathrm{S_t} = j \middle| \mathrm{S_{t-1}} = i\right]$ for $i = j = 1, 2$ in this case

	United States		Germany		Japan	
Parameter	Estimate	Std. Error	Estimate	Std. error	Estimate	Std. error
α	0.304	$(0.061)^2$	0.244	$(0.097)^1$	0.169	$(0.060)^2$
β	–0.037	(0.034)	0.021	(0.038)	0.063	(0.038)
c_1	2.249	$(0.281)^2$	2.301	$(0.354)^2$	2.148	$(0.284)^2$
c_2	7.146	$(1.747)^2$	7.326	$(2.562)^2$	9.785	$(1.409)^2$
a_1	0.039	(0.058)	0.005	(0.035)	0.032	(0.064)
a_2	0.173	(0.158)	0.226	$(0.091)^1$	0.151	$(0.060)^1$
p_{11}	0.973	–	0.991	–	0.982	–
p_{22}	0.939	–	0.985	–	0.972	–
h_1*	2.339	–	2.312	–	2.220	–
h_2*	8.644	–	9.469	–	11.521	–
ARCH(4)	0.75	(0.55)	1.70	(0.15)	2.27	(0.06)
RCM	55.7		34.9		40.9	

Note: The table gives the estimated coefficients calculated by Maximum Likelihood using the BFGS algorithm. Heteroskedasticity-consistent standard errors in parentheses. – ARCH(4) is an F-test statistic for the null hypothesis of no ARCH effects in standardised residuals up to lag 4 with p-values in brackets. – RCM is the regime classification measure as proposed by Ang and Bekaert (1998) which lies between 0 (perfect classification) and 100 (no information). Effective sample: 31 January 1980 to 16 September 1999 (1,025 usable observations). $^{1\,(2)}$ indicates significance at the 5% (1%) level. h_1* is the unconditional variance in the low volatility state, and h_2* is the unconditional variance in the high volatility state. They are calculated as the steady-state solutions to each state's variance equation, i.e.: $h_{S_t}^* = c_{S_t}/(1-a_{S_t})$ for $S_t = 1, 2$.

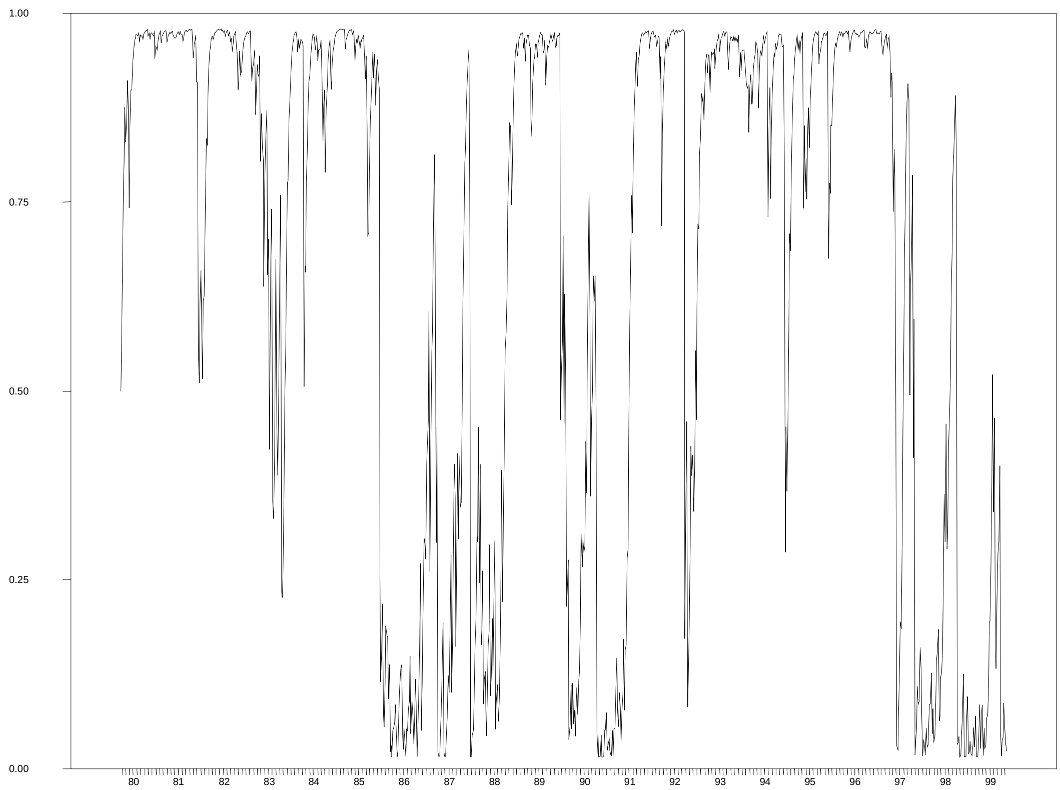
Also note that we specified the variance processes without a GARCH term. We can dispense with lagged conditional variances since they proved to be insignificant in all cases. This fact is consistent with the presumption that the near-unit root in the conditional variance process of conventional GARCH models (as mentioned above) does not reflect "true" volatility persistence, but instead results

[30] Ang and Bekaert (1998), p. 15, define the RCM statistic (here for two states) as: $RCM = 400 \cdot \frac{1}{T}\sum_{t=1}^{T} p_{1,t}(1-p_{1,t})$. In a perfectly classifying regime-switching model the conditional probability would always be infinitesimally close to 1 or 0, keeping the RCM at value 0. On the other hand, if the probabilities hover around 0.5, the model would provide no regime information, boosting the RCM to 100. The fact that the RCM for the German model is indeed rather low can be judged from the average product of regime probabilities RCM/400 = 0.087. It implies that the dominating regime probability on average equals 0.903, which is rather high.

as a bias from the neglect of structural breaks such as different variance regimes.[31] The fact that we can actually take out the GARCH terms without rendering the SWARCH model less powerful may be seen from Figure 4, which compares the conditional variance process for US stock returns of the SWARCH model with that of a GARCH model.[32] The conditional variance of the SWARCH model is calculated according to equations 7 and 8, i.e. the variance processes of each state are weighted by their time-varying conditional regime probability. The degree of overlap between the two time series is impressive, so that even a parsimonious SWARCH specification is able to generate rich volatility dynamics stemming from the non-linearities implied by Markov switching variance regimes.

Figure 3: Conditional probability of being in the low variance regime

From a SWARCH model of German stock returns



We are now in a position to calculate regime-dependent cross correlations, as is done by Ramchand and Susmel (1998). The low variance and high variance states in each market were identified using the classification system of Hamilton (1989), wherein an observation belongs to state 1 or 2 whichever state's conditional probability $p_{i,t} = \text{Prob}\left[S_t = i \middle| \Omega_{t-1}\right]$ is higher than 0.5.[33] Under this assumption, four possible states have to be considered in a bivariate setting. For instance, if we want to correlate US and German stock returns, the following four states emerge:[34]

---

31 Lamoureux and Lastrapes (1990) studied this point in more depth.

32 The GARCH process is taken from the bivariate US-German model in the constant correlation representation as given in Table 2, but any other estimated GARCH model for US returns produces almost identical results.

33 While Hamilton proposes the smoothed probabilities for defining regimes, we shall use the filtered probabilities instead, because they are also used for the calculation of the conditional variance process and owing to their ex ante nature.

34 Instead of estimating bivariate four-state SWARCH models, this paper focuses on separately calculated simple correlation coefficients for each of the four states. First, unrestricted four-state SWARCH models are difficult to estimate. The transition matrix alone contains 12 transition probabilities to be estimated without further restrictions. Second, the

$S_t = 1$: US variance low, German variance low

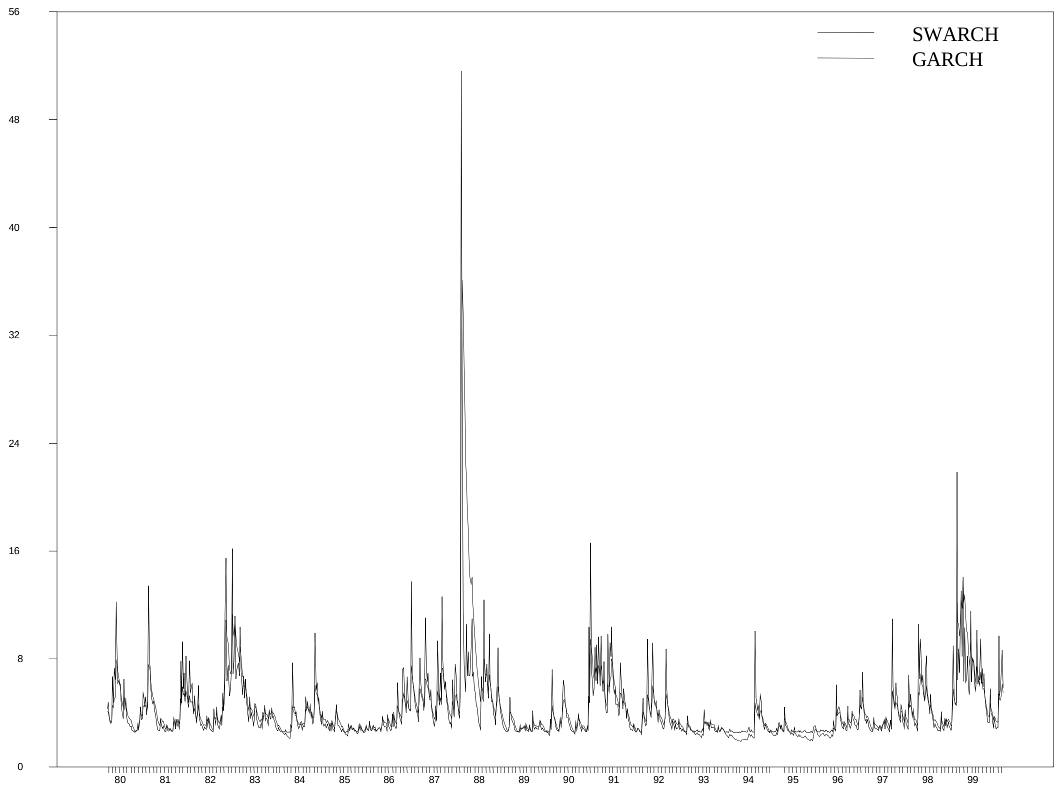
$S_t = 2$: US variance low, German variance high

$S_t = 3$: US variance high, German variance low

$S_t = 4$: US variance high, German variance high[35]

Figure 4: Conditional variance from a SWARCH and GARCH model

US stock returns



The results of the return correlations across these four states are given in Table 4.[36] They confirm the general hypothesis of correlations increasing along with volatility. Hence, "market turbulence matters" indeed. For example, the US-German correlation increases to 0.63 when both countries experience high volatilities (state 4) compared with 0.40 in the case of low volatilities (state 1). The same pattern holds for the remaining country pairs. The intermediate states suggest the following interpretation: the US market seems to dictate the degree of international stock price synchronisation. If US returns are in the high volatility state, the correlation with German and Japanese returns is also high, regardless of whether foreign returns belong to the high or to the low volatility state. Conversely, if US returns are in the low volatility state, the correlation with foreign returns also diminishes. Furthermore, the correlation between German and Japanese returns is minor except when both returns become more

---

two-step, "system-free" procedure provides a tractable way of obtaining state-dependent correlations even when a larger set of countries or asset classes is considered. However, this entails the disadvantage of not obtaining an independent estimate of the conditional regime probabilities which could be used for forecasting purposes.

35 Comparing the conditional variance series of different countries suggests that the distinction between four states does make sense. Figure 3, for example, shows volatility hikes in Germany which occur independently of volatility movements in the United States, and vice versa. Thus, volatility cycles are generally not fully synchronised, which argues against the general validity of the contagion hypothesis.

36 We also calculated the correlations between the residuals from the SWARCH models instead of total returns, but the results were absolutely unchanged to the first and second decimal place.

volatile at the same time. This may again be the result of a common dependency on US returns. It is also worth mentioning that each state for each pair of countries occurs sufficiently often to enable a reasonable estimate of the corresponding correlation coefficient to be obtained, although tranquil periods are more frequent than turbulent ones.

Table 4
Stock market cross correlation in different volatility regimes

	Correlation	Observations
United States vs Germany		
State 1: US low, Germany low	0.40	601
State 2: US low, Germany high	0.44	185
State 3: US high, Germany low	0.61	88
State 4: US high, Germany high	0.66	151
United States vs Japan		
State 1: US low, Japan low	0.30	542
State 2: US low, Japan high	0.27	244
State 3: US high, Japan low	0.44	102
State 4: US high, Japan high	0.59	137
Germany vs Japan		
State 1: Germany low, Japan low	0.24	531
State 2: Germany low, Japan high	0.23	158
State 3: Germany high, Japan low	0.21	113
State 4: Germany high, Japan high	0.42	223

Note: State classification according to the conditional regime probabilities derived from univariate SWARCH(2,1) models for weekly stock returns. Total sample: 31 January 1980 to 16 September 1999 (1,025 usable observations).

4.2 Correlation across major bond markets

Table 5 presents the estimated coefficients of the bivariate GARCH models for each pair of US, German and Japanese bond returns. Essentially, the models yield the expected results. First, bond returns are lower and less volatile than stock returns, which is properly reflected in the estimated unconditional means and variances. Second, although not economically significant, bond returns contain some predictable elements, as is evidenced by the statistical significance of seven out of 12 autoregressive coefficients in the mean equations. Third, the conditional variance equations look quite familiar, like their stock market counterparts. However, this holds only for the constant correlation representation. The diagonal representation delivers some awkward-looking conditional covariance equations for the bivariate models of Japanese returns, which makes us less confident in this specification.[37] Instead, the time-varying correlation between US and German returns follows rather smooth and extended cycles around its steady state (see Figure A2 in the Appendix). Moreover, there exists no discernible time trend in the coefficient, suggesting a structural break with higher correlation in the recent past. Overall, the GARCH models prove again that the short-term linkage between German and US returns is much higher and, at the same time, more stable than the correlation of either of these countries with Japanese bond returns.

[37] The structure of these covariance equations implies that the time series of covariances and, hence, the correlation coefficients regularly jump up and down around their medium-term trend. This behaviour is economically unconvincing and leads to the rejection of this specification. Technically speaking, it results from the fact that bond prices in Japan quite frequently do move in the opposite direction to US or German prices, but not for long enough; in turn, this may be caused economically by asymmetric market conditions such as monetary and fiscal policy shocks.

Table 5
Bivariate AR(1)-GARCH(1,1) models for major bond markets

(1) $r_{j,t} = \alpha_j + \beta_j r_{j,t-1} + \varepsilon_{j,t}$ for $j = x, y$ (country x vs country y)

(5a) $h_{j,t} = c_j + a_j \varepsilon^2_{j,t-1} + b_j h_{j,t-1}$

(6) $h_{xy,t} = \rho(h_{x,t-1} h_{y,t-1})^{0.5}$ constant correlation representation

(5b) $h_{xy,t} = c_{xy} + a_{xy} \varepsilon_{x,t-1} \varepsilon_{y,t-1} + b_{xy} h_{xy,t-1}$ diagonal representation

	Constant correlation representation						Diagonal representation					
	US vs DE		US vs JP		DE vs JP		US vs DE		US vs JP		DE vs JP	
α_x	0.047	(0.038)	0.038	(0.035)	0.051	(0.021)^{1}	0.046	(0.031)	0.042	(0.031)	0.049	(0.022)^{1}
β_x	–0.038	(0.031)	–0.016	(0.038)	0.077	(0.039)^{1}	–0.046	(0.039)	–0.019	(0.033)	0.081	(0.027)^{2}
α_y	0.047	(0.025)	0.067	(0.031)^{1}	0.073	(0.026)^{2}	0.044	(0.026)	0.068	(0.024)^{2}	0.074	(0.025)^{2}
β_y	0.077	(0.034)^{1}	0.086	(0.037)^{1}	0.090	(0.036)^{1}	0.069	(0.039)	0.091	(0.039)^{1}	0.095	(0.044)^{1}
c_x	0.087	(0.035)^{1}	0.075	(0.043)	0.019	(0.007)^{2}	0.080	(0.033)^{1}	0.074	(0.035)^{2}	0.022	(0.007)^{2}
c_y	0.028	(0.011)^{1}	0.076	(0.023)^{2}	0.075	(0.021)^{2}	0.033	(0.016)^{1}	0.074	(0.020)^{2}	0.080	(0.022)^{2}
c_{xy}	–	–	–	–	–	–	0.018	(0.006)^{2}	0.296	(0.052)^{2}	0.225	(0.051)^{2}
a_x	0.078	(0.028)^{2}	0.072	(0.024)^{2}	0.114	(0.027)^{2}	0.079	(0.025)^{2}	0.072	(0.022)^{2}	0.108	(0.022)^{2}
a_y	0.116	(0.031)^{2}	0.143	(0.037)^{2}	0.135	(0.036)^{2}	0.105	(0.032)^{2}	0.139	(0.033)^{2}	0.126	(0.034)^{2}
a_{xy}	–	–	–	–	–	–	0.053	(0.011)^{2}	–0.026	(0.021)^{2}	–0.034	(0.026)^{2}
b_x	0.839	(0.047)^{2}	0.856	(0.054)^{2}	0.855	(0.026)^{2}	0.844	(0.043)^{2}	0.857	(0.045)^{2}	0.853	(0.024)^{2}
b_y	0.832	(0.040)^{2}	0.756	(0.054)^{2}	0.763	(0.047)^{2}	0.831	(0.055)^{2}	0.762	(0.042)^{2}	0.763	(0.049)^{2}
b_{xy}	–	–	–	–	–	–	0.893	(0.016)^{2}	–0.805	(0.121)^{2}	–0.627	(0.240)^{2}
ρ	**0.472**	(0.026)^{2}	**0.215**	(0.036)^{2}	**0.267**	(0.032)^{2}	–	–	–	–	–	–
h_x*	1.040	–	1.042	–	0.624	–	1.040	–	1.041	–	0.580	–
h_y*	0.549	–	0.745	–	0.733	–	0.523	–	0.744	–	0.719	–
ρ*	–	–	–	–	–	–	**0.451**	–	**0.183**	–	**0.210**	–

Note: The table gives the estimated coefficients calculated by Maximum Likelihood using the BFGS algorithm. Heteroskedasticity-consistent standard errors in parentheses. Effective sample: 26 January 1984 to 16 September 1999 (817 usable observations). $^{1\ (2)}$ indicates significance at the 5% (1%) level. h_j* is the unconditional variance of country j's unexpected return, and ρ* is the unconditional correlation coefficient, both calculated as the steady-state solutions to the variance and covariance equations 5a and 5b and using the definition of the correlation coefficient.

In testing for regime dependency of bond market correlation, our two-state SWARCH model failed to identify different volatility regimes in the US case.[38] We therefore have recourse to the "threshold" approach, where an exogonenously defined threshold value separates high from low volatility observations.[39] Accordingly, an observation belongs to the high (low) volatility regime when squared returns are higher (lower) than the threshold value. While in most cases the threshold is set to the sample standard deviation, we apply different scaling parameters to the unconditional standard deviation in order to mitigate the problem of ad-hocery. The corresponding regime-dependent cross correlations are presented in Table 6. Again, the results strongly confirm the positive relation between market turbulence and international correlation. For example, irrespective of the scaling parameter, the US-German correlation more than doubles when both countries move together from a low volatility to a high variance state. In the US-Japanese case, correlation even increases about five times on average, although it never reaches the absolute values of the US-German linkage. The mixed states 2 and 3 only matter for the relationship between US and German bond returns. The correlation is higher than in the

[38] For Germany and Japan, instead, we obtained reasonable results.

[39] See Longin and Solnik (1995).

“low-low state” and almost identical, regardless of whether prices move more in the United States or in Germany. This pattern suggests that larger price movements in one market, which may result from pure idiosyncratic shocks (such as monetary policy shocks), do always spill over to the other market to some degree and thus tighten the measured linkage significantly, without necessarily “exporting” the underlying market uncertainty. Experience suggests that this typically occurs when a market is said to “decouple” from the other, with relative interest rates gradually adjusting to asymmetric outlooks for their fundamental factors while both rates still move synchronously.[40]

Table 6
Bond market cross correlation in different volatility regimes

	η = 0.75		η = 1.00		η = 1.50	
	Corr.	Nobs.	Corr.	Nobs.	Corr.	Nobs.
United States vs Germany						
State 1: US low, Germany low	0.25	331	0.28	468	0.33	648
State 2: US low, Germany high	0.35	153	0.47	123	0.65	69
State 3: US high, Germany low	0.37	179	0.49	140	0.60	73
State 4: US high, Germany high	0.71	154	0.79	86	0.83	27
United States vs Japan						
State 1: US low, Japan low	0.10	356	0.10	483	0.12	653
State 2: US low, Japan high	0.09	128	0.10	108	0.38	64
State 3: US high, Japan low	0.13	217	0.25	167	0.24	80
State 4: US high, Japan high	0.44	116	0.54	59	0.62	20
Germany vs Japan						
State 1: Germany low, Japan low	0.12	379	0.10	504	0.17	659
State 2: Germany low, Japan high	0.11	131	0.42	104	0.44	62
State 3: Germany high, Japan low	0.12	194	0.28	146	0.22	74
State 4: Germany high, Japan high	0.53	113	0.55	63	0.71	22

Note: “Corr.” And “Nobs.” stand for “correlation coefficient” and “number of observations”, respectively. State classification according to an exogenous threshold based on the unconditional standard deviation σ of weekly stock returns r_t scaled by the parameter η:

low volatility state, if $|r_{j,t}| < \eta \cdot \sigma_j$

high volatility state, if $|r_{j,t}| \geq \eta \cdot \sigma_j$.

Assuming normally distributed returns, η-values of 0.75, 1.00 and 1.50 predict that approximately 45%, 30% and 13% of absolute returns lie above the threshold, respectively. Total sample: 26 January 1984 to 16 September 1999 (817 usable observations).

Before turning to the empirical results for different German market segments, we have to add a few words of caution, however. As recent studies have demonstrated, even substantial increases in correlation during market turbulence must not be interpreted per se as conclusive evidence of contagion opposed to normal interdependence.[41] In fact, the sample correlation should always increase (decrease) relative to its constant population moment when the sampling variance of linearly dependent return variables exceeds (falls below) its “true” unconditional variance (see equation 1 and the corresponding theorem in Loretan and English (1999, this volume)). Hence, upward jumps in asset return correlations in periods of high volatility are to be expected even if the true unconditional correlation – which measures normal interdependence – remains unchanged. The presumed

40 How level linkages (“convergence”) and comovements (“synchronisation”) can be estimated separately within a single empirical framework is shown by Kremer (1999).

41 See Boyer et al. (1999), Forbes and Rigobon (1999) and Loretan and English (1999, this volume).

breakdown in measured correlation may therefore result from such normal interdependence rather than from contagion accompanied by a shift in the unconditional distribution of asset returns.[42]

How should our results be interpreted in the light of this sampling-bias argument? As a kind of robustness check, we calculated "theoretical" or "expected" correlations between US and German or US and Japanese stock returns according to Loretan and English's equation 1 under the assumptions that, first, the variance of US returns in the low volatility regime equals the unconditional variance and, second, that volatility regimes are fully synchronised in all countries so that only two states can occur. In the US-German case, the increase in the variance of US returns over high volatility periods justifies an increase in the correlation from 0.41 in tranquil times to 0.58 in turbulent times. The last value comes very close to the measured correlation in the high volatility regime of 0.60. In the US-Japanese case, by contrast, the expected correlation only increases from 0.28 to 0.41, which is substantially lower than the measured correlation of 0.55 in the high volatility state.

This mixed evidence implies some ambiguity in the interpretation of our results, i.e. it remains an open question whether observable changes in stock or bond market correlations result from contagion or merely reflect normal but strong international market linkages. Both hypotheses are observationally equivalent. However, we wish to mention one argument which favours the contagion hypothesis. Regime-switching models actually try to identify shifts in the underlying asset return distributions which may result from significant differences in market participants' behaviour during periods of stress. Since we have found strong evidence that variance regimes switch over time, it is also plausible to allow unconditional ("structural") cross-market correlations to switch with changes in the variance regimes.

5. Spreading of international volatility spillovers through the national financial markets: do market segments matter?

Volatility spillovers measured on the basis of benchmark segments, such as the yield of 10-year government bonds, do not necessarily reflect the situation in the market as a whole. Instead, a certain decoupling of particular segments of national markets may occur in the wake of international volatility spillovers. If asset price movements in a very general sense are interpreted as the result of information processing, several reasons may be put forward for such a market segmentation: first, the information relevant for price formation may differ between market segments; second, even if the information basis is the same, the processing of information might differ systematically according to the different groups of investors which are most active in the respective markets; third, even if information input and processing are congruent over market segments, the price effect may deviate owing to differing transaction costs or market liquidity.

In order to test the "market segmentation" hypothesis, we calculate return correlations over different volatility regimes between each German stock and bond market segment and the corresponding US benchmark market. The selection of national market segments is based on the presumption that they differ with respect to the set of price-relevant information, the dominant market participants and market liquidity from the 10-year government benchmark bond and the value-weighted DS German equity index, respectively. If the structural differences really matter, they should show up in different international correlation patterns. Table 7 summarises some structural features of the German market segments. In the stock market, the blue chip DAX segment is by far the most liquid and presumably also the most international one. In contrast to this, the medium-sized companies represented in the MDAX as well as the small SMAX shares are far less actively traded. Additionally, different information sets might be relevant for each market if one supposes that MDAX and SMAX companies are less international (in terms of business activity) than those in the DAX.

[42] Actually, the empirical results presented in Forbes and Rigobon (1999) as well as Loretan and English (1999, this volume) argue against the contagion hypothesis.

Table 7
Features of German securities markets

Market segment	Market capitalisation (euro bn)	Number of issues	Average market value per issue outstanding (euro bn)	Futures contracts traded	Turnover/ market capitalisation[1]	Foreign participation[2]
Stock market						
DS Germany	965.4			no derivative	n.a.	n.a.
DAX	791.2	30	26.4	1.088[3]	0.68	n.a.
MDAX	116.7	70	1.7	74[3]	0.24	n.a.
SMAX	19.9	107	0.2	no derivative	0.29	n.a.
Bond market						
Bund 10-yr	54.1	4	13.5	99.093[4]	n.a.	130%
Bund 7-yr	22.5	2	11.3	no derivative	n.a.	
Bund 5-yr	47.6	7	6.8	32.509[4]	n.a.	
Bund 2-yr	50.6	8	6.3	10.978[4]	n.a.	75%
Pfandbriefe 10-yr	177.3	2.94	0.1	no derivative	n.a.	30%

Note*:* Figures are as of August 1999 or as indicated.

[1] Average monthly turnover from September 1998 to August 1999 divided by market capitalisation as of end-August 1999.
[2] Cumulated net purchases by foreigners from January 1994 to June 1999 related to total net issues. [3] In billions of euros.
[4] Number of contracts traded from January 1999 to August 1999 in thousands.

Sources: Deutsche Börse; Deutsche Bundesbank; Eurex Germany; own calculations.

For the bond market, the 10-year government bond segment is clearly the most liquid one (as is indicated by the average size of issues and the availability of one of the most actively traded futures contracts worldwide as a hedging instrument) and also the most "international" one. (The available statistics do not allow for a separation of ownership for individual issues. However, anecdotal evidence suggests that international participation – and particularly short-term position-taking – is concentrated in this segment.) The five- and two-year maturities can also be assessed as very liquid and "international", although less so than the 10-year segment. A stark contrast exists between the structure of the 10-year bund and bank bond segment. The latter is relatively scattered and international participation is only a fraction of that of the bund market (the picture would be different for the liquid Jumbo Pfandbriefe; however, it is not possible to separate them statistically). Compared with the stock market, the information relevant for bond prices could mainly depend on the maturity of the instrument (giving domestic monetary policy a particularly strong and more direct impact at the short end of the yield curve).

5.1 Stock market

The correlation of stock returns between the US market and the different segments of the German market supports the presumption sketched out above that less liquid and less international market segments may be less prone to international turbulence (see Table 8). The correlation pattern between the US market and the DAX is again (see Table 1) very similar to that of the DS index due to the dominance of the blue chips in the latter. The correlation increases by about 50% if both markets switch from a low volatility regime to a high volatility regime at the same time. By contrast, the correlation of MDAX and SMAX shares with the US stock market is significantly lower than that of the DAX if market conditions are calm in Germany. However, all German markets exhibit a similar comovement with US stock prices if Germany is in a high volatility regime. But, in both cases, MDAX and SMAX correlation is broadly unaffected by a switch in the volatility regime in the United States.

Table 8
Cross correlation with the US stock market for different market segments in Germany over different volatility regimes

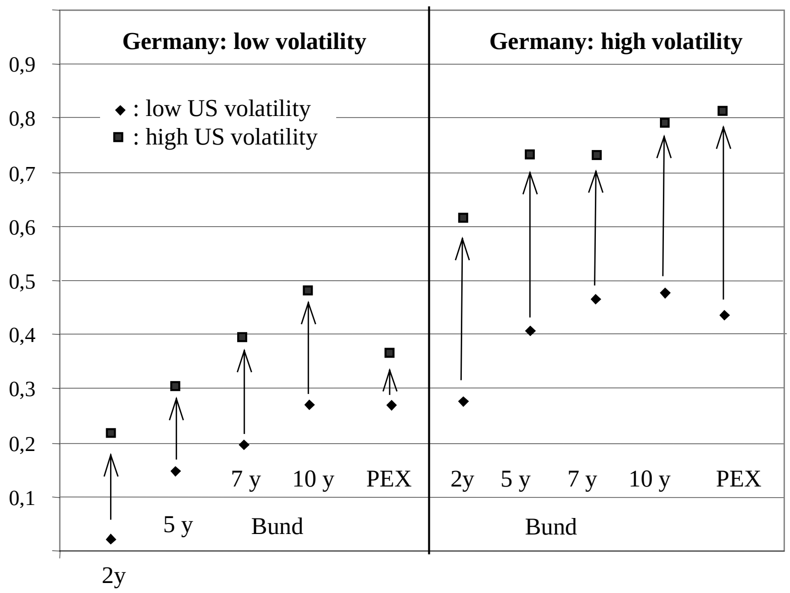
	Correlation with DS United States: German market segment			
Volatility regime	DS Germany	DAX	MDAX	SMAX
Germany low				
US low (364)	0.46	0.44	0.39	0.28
US high (13)	0.51	0.54	0.31	0.26
Germany high				
US low (99)	0.58	0.54	0.54	0.53
US high (94)	0.65	0.65	0.54	0.55

Note: Volatility regimes identified by univariate SWARCH(2,1) models for US and German total market returns (DS indices). Effective sample: 21 October 1988 to 16 September 1999. Number of regime observations in parentheses.

5.2 Bond market

For the bond market, the level of return correlations under different volatility regimes and the impact of a volatility regime shift in the US bond market on the various German market segments support the view that market segments matter (see Figure 5). If both the domestic and the US market are in a low volatility regime, correlation is generally low but increases with longer maturities of German government bonds. This correlation pattern may simply be explained by the fact that the substitutability of 10-year US government bonds and German bonds decreases with shorter maturities

Figure 5: Volatility regime shifts in the US bond market and their impact on the correlation with the German bond market*



*Correlation of weekly returns on 10- year US government bonds and the return in the respective German market segment. Volatility regimes identified by exogenous threshold for unconditional standard deviation (UStd) with low variance regime: $|r(t)| < 1.0*UStd$, and high variance regime: $|r(t)| > 1.0*UStd$.

of the latter. From the viewpoint of the information contained in bond prices, this may be a reflection of cyclical differences in domestic factors – namely monetary policies – becoming less important with increasing maturities relative to long-term expectations about growth and inflation. The correlation between the highly liquid 10-year bunds and the less liquid Pfandbriefe, on the one hand, and US bonds, on the other, differs only slightly. This may be seen as an indication that arbitrage between both domestic market segments works well during calm periods. A reason for this could be that market liquidity plays a minor role in calm periods.

This picture changes during episodes of high volatility: if the US market switches to a high volatility regime (while Germany remains in the low volatility state), correlation between German government bonds and US Treasuries almost doubles, irrespective of the maturity of the former. The Pfandbrief segment, in contrast, exhibits only a slightly higher correlation. An explanation for this phenomenon might be that the German government bond market, as the most liquid and international segment, is directly affected by the reallocation of international bond portfolios induced by the US market. The Pfandbrief segment might remain relatively unaffected by these transactions because domestic portfolios do not need to be reallocated against a background of still-low domestic volatility. This view changes dramatically if the domestic market switches to a high volatility regime, too. In this case, the correlation between the Pfandbriefe and US Treasuries jumps to 0.81, about the level of the bunds' correlation.

6. Conclusion and outlook

The purpose of this paper is twofold. First, we suggest GARCH techniques to measure international asset price linkages when higher-frequency data are used. The proposed measure is either a constant or a time-varying correlation coefficient of (unexpected) weekly asset returns. Second, we investigate whether correlations between German and US bond and stock returns depend on different volatility regimes and, moreover, whether they vary across benchmark products and minor market segments in Germany. The results generally support the view that both the volatility regime and the market structure are important for the strength of international price linkages. Given these results, two questions arise: first, "How can the empirical evidence presented in this paper be interpreted and explained economically?", and second, "What are the policy implications at the micro and the macro level?".

GARCH models are essentially descriptive in nature. As in most applications, the models employed here were not derived from first economic principles and thus lack a straightforward theoretical interpretation. Consequently, the theory behind the model has to be superimposed a posteriori. Furthermore, the forces that drive short-term asset prices are modelled as "latent" and hence unobservable variables. Both issues leave a wide range of options among competing theories for the model's interpretation. Unless the theory imposes a certain structure on the model which leads to testable restrictions, this choice will always be ad hoc and somewhat arbitrary.

A very general approach to interpretation is to view asset price movements as the result of an information-processing activity, comprising the arrival of new information, its analysis by market participants and the interplay of market transactions carried out on the basis of this new information. In this perspective, ARCH effects in high-frequency data can be seen as a manifestation of serial correlation or "time dependence" in the amount of information or the quality of information arriving to the market per period of time, i.e. short-term asset returns are driven by the amount or quality of news reaching the market in clusters.[43] This view can be broadened to include the time it takes market participants to assess the information fully (information-processing hypothesis) and the price dynamics created by the responses of market agents to news. For example, traders with heterogeneous

43 For different interpretations of ARCH models, see Bera and Higgins (1993), pp. 322-30, and Bollerslev et al. (1992), p. 40f.

prior beliefs and private information may need some time for information processing and trading – after news has come in – to resolve the expectational differences.[44]

This framework is able to explain volatility clustering, but not necessarily the closer international comovement of assets prices – i.e. contagion – in turbulent periods. To explain this fact, one has to make assumptions about the nature of shocks behind asset price movements in each market. For example, the study by Engle et al. (1990) suggests that the volatility of short-term asset prices derives mostly from common and hence "international" shocks ("meteor showers") and less from changes in country-specific fundamentals ("heat waves"). Adopting this framework, we could argue that, first, more tranquil periods are dominated by independent country-specific shocks. The independence assumption implies that international price correlation tends to be lower in such periods. Second, strong turbulence usually affect markets worldwide like a meteor shower. As a consequence, asset prices in high volatility periods are mainly driven by a common factor, the international shock, and hence show a higher degree of comovement.

The meteor shower/heat wave hypothesis provides an explanation for high correlation in turbulent periods only if international shocks are associated systematically with higher price volatility than domestic ones. One theoretical argument to support this view might be that a global shock triggers portfolio reallocation on a much larger scale than a regional one. However, it is not sufficient to explain why asset prices in various domestic market segments react differently to the same global shock. This leads to the point that not only the nature of information seems to matter for international correlation, but also the institutional setting in specific markets – such as their liquidity, the presence of foreign investors, or the role of institutional investors – and the behaviour of different groups of market participants (whose reaction to shocks might also be regime-dependent). Taken together, a better understanding of information processing and the market micro-structure appears necessary and should be one focal point of future research.

From a policy-oriented point of view, research in this direction also appears important because regime and market-segment dependence of asset price correlation could have implications for risk management and portfolio diversification, and, related to that, the measurement of value at risk (VaR). One obvious implication of the results presented here is that proper stress testing has to play a pivotal role in risk management. VaRs which are calculated for different volatility scenarios have to take into account changes in conditional cross correlations which are associated with changes in variance regimes. With respect to this, it might be further asked in what way changing market structures and conditions could be integrated into the measurement and management of market risk.

A second point that might be put forward is that certain "domestic" market segments might provide a shelter against international volatility spillovers. This could eventually challenge traditional diversification strategies and might provide an argument in favour of a home bias. However, serious doubts have to be voiced as to whether this conclusion would be justified. First, a lower return correlation does not necessarily mean that diversifying in other domestic market segments provides an efficient shelter against foreign asset price shocks. Lower return correlation has a decreasing effect on portfolio risk only if it is not compensated by higher idiosyncratic market, credit, or liquidity risk – which all affect the volatility of the returns on these financial instruments. Additionally, the attempt to exploit a diversification potential within different domestic market segments would probably change the pattern of return correlation between markets. Again, these arguments support the view that a better understanding of the micro-structure in individual markets is necessary.

[44] See Engle et al. (1990), p. 376.

Appendix: Data description

All asset price data used in this study are taken from the Datastream database. National stock prices are represented by the Datastream Global Equity Index for Germany, the United States and Japan (TOTMKBD, TOTMKUS, TOTMKJP). This price index is a broad-market value-weighted index: it covers at least 75–80% of the total market capitalisation; local closing prices of individual stocks are aggregated using their market values as weights.

Bond market prices are represented by Datastream Government Bond Indices for 10-year benchmark bonds in Germany, the United States and Japan (BMBD10Y, BMUS10Y, BMJP10Y). This benchmark index is based, in most cases, on a single bond. In general, the benchmark bond is the latest issue within a given maturity band; however, consideration is also given to liquidity, issue size and coupon. Furthermore, the index uses clean prices at local closing dates.

Stock and bond market returns are calculated as weekly percentage changes (usually Thursday to Thursday) in the log of the corresponding price index. Hence, we ignore exchange rate changes when calculating local returns. This is equivalent to the assumption that international investments are fully hedged against currency risk, but without cost.

Supplementary tables and figures

Table A1
Univariate summary statistics on weekly returns

Market	Mean	Min.	Max.	SD	SK	K	JB	AR(1)	Q(4)	ARCH(4)
Stock market (effective sample: 10 January 1980 to 16 September 1999)										
DS US	0.26	–16.01	7.69	2.07	–0.82	4.97	1,170.45	0.00	0.64	25.11
DS JO	0.13	–12.35	13.84	2.42	–0.17	3.58	554.09	–0.00	12.38	28.08
DS DE	0.20	–15.59	10.37	2.20	–0.90	5.04	1,225.37	0.08	16.01	33.49
DAX	0.21	–13.01	11.62	2.64	–0.48	2.16	133.24	–0.05	3.35	18.10
MDAX [1]	0.17	–13.24	9.86	2.08	–0.92	5.13	709.20	0.06	12.89	20.76
SMAX [1]	0.10	–10.22	5.29	1.77	–0.92	4.31	522.37	0.21	49.84	18.01
Bond market (effective sample: 12 January 1984 to 16 September 1999)										
10-yr US	0.03	–4.02	5.37	1.01	0.05	1.51	77.75	0.01	6.06	6.55
10-yr JP	0.04	–4.63	3.93	0.88	–0.65	5.11	949.64	0.12	36.50	23.85
10-yr DE	0.02	–3.85	3.99	0.72	–0.49	2.81	301.87	0.09	17.62	13.32
7-yr DE	0.02	–2.37	2.75	0.54	–0.61	2.33	236.07	0.10	22.34	8.63
5-yr DE	0.01	–1.57	1.67	0.40	–0.39	1.42	90.08	0.14	37.71	6.50
2-yr DE	0.01	–1.17	1.63	0.28	–0.19	2.70	254.61	0.18	59.57	2.71
10-yr PEX [2]	0.01	–2.78	1.94	0.59	–0.75	2.30	193.12	0.12	21.61	5.39

Note: SD = standard deviation; SK = skewness; K = excess kurtosis; JB = Jarque-Bera statistic for normality; AR(1) = first-order autocorrelation coefficient; Q(4) = Ljung-Box statistic for autocorrelation up to order 4; ARCH(4) = ARCH test with four lags (for squared returns).

[1] MDAX and SMAX sample starts on 6 October 1988. [2] PEX sample starts in 7 January 1988.

Figure A1: Conditional variances and correlation between US and German stock returns

Bivariate AR(1)-GARCH(1,1), diagonal representation: variances (left scale), correlation (right scale)

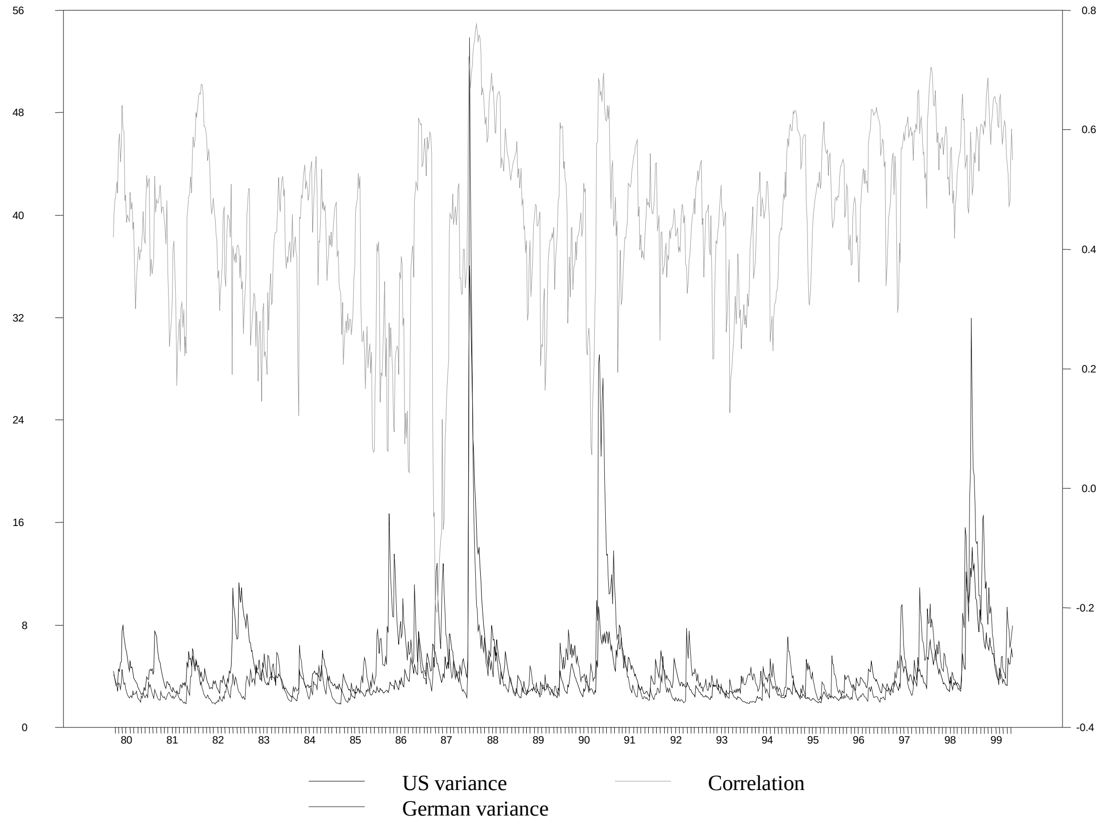
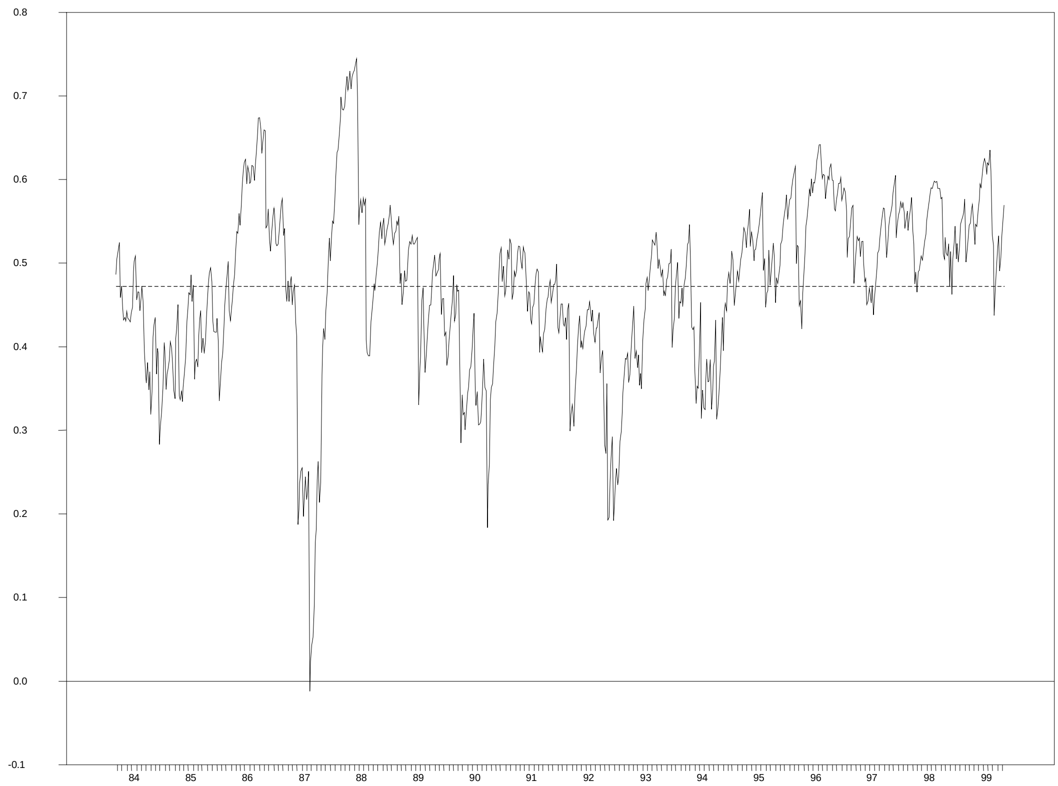


Figure A2: US–German bond return correlation from bivariate GARCH models

Constant correlation representation (dashed line) and diagonal representation (solid line)



Bibliography

Ang, A and G Bekaert (1998): "Regime switches in interest rates". *NBER Working Paper*, No. 6508, April.

Baig, T and I Goldfajn (1999): "Financial market contagion in the Asian crisis". *IMF Staff Papers*, 46, pp. 167-95.

Bera, A K and M L Higgins (1993): "ARCH models: properties, estimation and testing". *Journal of Economic Surveys*, 7, pp. 305-62.

Bodart, V and P Reding (1999): "Exchange rate regimes, volatility and international correlations on bond and stock markets". *Journal of International Money and Finance*, 18, pp. 133-51.

Bollerslev, T (1990): "Modelling the coherence in short-run nominal exchange rates: a multivariate generalised ARCH approach". *Review of Economics and Statistics*, 72, pp. 498-505.

Bollerslev, T, R F Engle and J M Wooldridge (1988): "A capital asset pricing model with time-varying covariances". *Journal of Political Economy*, 96, pp. 116-31.

Bollerslev, T, R Y Chou and K F Kroner (1992): "ARCH modeling in finance". *Journal of Econometrics*, 52, pp. 5-59.

Cai, J (1994): "A Markov model of switching-regime ARCH". *Journal of Business and Economic Statistics*, 12, pp. 309-16.

Campbell, J Y, A W Lo and A C MacKinlay (1998): *The econometrics of financial markets*. Princeton University Press, Princeton, N.J.

Cochrane, J H (1999): "New facts in finance". Federal Reserve Bank of Chicago, *Economic Perspectives*, 23, pp. 36-58.

Deutsche Bundesbank (1997): "The implications of international influences for capital market rates". *Monthly Report*, Vol. 49, No. 7, pp. 23-40, July.

Domanski, D and M Kremer (1998): "What do asset price movements in Germany tell monetary policy makers?" Bank for International Settlements, *BIS Conference Papers*, Vol. 3, pp. 24-44.

Domanski, D and M Kremer (1999): "What is behind equity price movements in Germany?" in E Baltensperger (ed.), *Transmissionsmechanismen der Geldpolitik*, Schriften des Vereins für Sozialpolitik, Neue Folge Band 264, Duncker und Humbolt, Berlin, pp. 111-41.

Engle, R F, T Ito and W-L Lin (1990): "Meteor showers or heat waves? Heteroskedastic intra-daily volatility in the foreign exchange market". Econometrica, 58, pp. 525-542, reprinted in R F Engle (ed.), *ARCH. Selected readings*, Oxford University Press, Oxford (1995), pp. 375-94.

Forbes, K and R Rigobon (1999): "No contagion, only interdependence". *NBER Working Paper*, No. 7267, July.

Gray, S F (1996): "Modeling the conditional distribution of interest rates as a regime-switching process". *Journal of Financial Economics*, 42, pp. 27-62.

Hamilton, J (1989): "A new approach to the economic analysis of nonstationary time series and the business cycle". *Econometrica*, 57, pp. 357-84.

Hamilton, J (1994): *Time series analysis*. Princeton University Press, Princeton, N.J.

Hamilton, J and R Susmel (1994): "Autoregressive conditional heteroskedasticity and changes in regime". *Journal of Econometrics*, 64, pp. 307-33.

Hansen, B E (1992): "The likelihood ratio test under non-standard conditions: testing the Markov trend model of GNP". *Journal of Applied Econometrics*, 7, pp. S61-S82.

Herwartz, H and H-E Reimers (1999): "Dynamic relationships between international bond markets". Mimeo.

International Monetary Fund (1998): *World economic outlook and international capital markets – interim assessment.* Washington, D.C.

Kim, C-J and C R Nelson (1999): *State-space models with regime switching*. The MIT Press, Cambridge, MA, and London, England.

Koch, P D and T W Koch (1991): "Evolution in dynamic linkages across daily national stock indexes". *Journal of International Money and Finance*, 10, pp. 231-51.

Kremer, M (1999): "Die Kapitalmarktzinsen in Deutschland und den USA: Wie eng ist der Zinsverbund? Eine Anwendung der multivariaten Kointegrationsanalyse". Economic Research Group of the Deutsche Bundesbank, *Discussion Paper* 2/99, February.

Lamoureux, C G and W D Lastrapes (1990): "Persistence in variance, structural change and the GARCH model". *Journal of Business and Economic Statistics*, 5, pp. 121-29.

Longin, F and B Solnik (1995): "Is the correlation in international equity returns constant: 1960–1990?" *Journal of International Money and Finance*, 14, pp. 3-26.

Loretan, M and W B English (1999): "Evaluating 'correlation breakdowns' during periods of market volatility". Bank for International Settlements, *BIS Conference Papers*, this volume.

Ramchand, L and R Susmel (1998): "Volatility and cross correlation across major stock markets". *Journal of Empirical Finance*, 5, pp. 397-416.

White, H (1982): "Maximum likelihood estimation of misspecified models". *Econometrica*, 50, pp. 1-25.

International transmission and volume effects in G5 stock market returns and volatility

Sanvi Avouyi-Dovi and Eric Jondeau[1]

1. Introduction

An extensive literature has studied stock market returns and volatility. The attempts to clarify links between return and its theoretical determinants have led researchers to investigate several areas. Return-volatility interactions, trading volume effects and international transmission mechanisms appear to be the most promising of these.

Seminal papers by Mandelbrot (1963) and Fama (1965) have shown that volatility is time varying. Portfolio models suggest that volatility may play a central role in the determination of return, since a riskier asset is supposed to yield a higher return. This link has been studied through ARCH-in-Mean models, in which volatility is directly introduced as an explanatory variable of return (as in Engle et al. (1987) or French et al. (1987)). Conversely, Schwert (1990), among others, has shown that a shock to returns may have an asymmetric (or leverage) effect on volatility, depending on the sign of the shock: a negative shock on return generally implies a greater increase of volatility than a positive shock does, everything else being equal. These interactions between return and risk appear to be robust in explaining price dynamics of most financial assets (stock markets, exchange markets, etc.).

International transmission mechanisms were first identified between stock returns (Eun and Shim (1989)). Subsequently, interest has focused on volatility transmission between stock markets. Indeed, work on volatility spillovers on currency markets (Engle et al. (1990)) has recently been extended to stock markets by Hamao et al. (1990), Koutmos and Booth (1995) and Booth et al. (1997).

The role of trading volumes in return formation has been pointed out by many authors (see Tauchen and Pitts (1983) and Karpoff (1987) for surveys). Such a relation may be based on theoretical arguments (Copeland (1976) or Epps and Epps (1976) for a volume-volatility relation; Epps (1975) or Jennings et al. (1981) for a volume-return relation); but it is more often based on empirical evidence (Karpoff (1987)). Most studies have shown a positive correlation between volume and absolute returns, or volatility, on most asset markets: for instance, Schwert (1989) or Gallant et al. (1992) on stock markets, or Bessembinder and Seguin (1993) on futures markets. Moreover, as suggested in Harris and Gurel (1986) and Karpoff (1988), trading volumes and returns may be positively correlated (although this correlation is often weak). Lastly, Gallant et al. (1992) conducted a systematic long-run analysis of possible correlations between returns, volatility and trading volume. They have shown that volume plays a central role in explaining links between returns and volatility: indeed, they obtain a negative link between returns and volatility without including volume in the relation, but a positive link when volume is taken into account; moreover, the asymmetric effect decreases when volume is introduced in the dynamics of volatility. This empirical evidence on the links between volume, return and volatility suggests including volume as an explanatory variable in both return and volatility equations. But these three variables should actually be determinated simultaneously. This appears to be a difficult task. However, Jacobs and Onochie (1998) estimate a bivariate GARCH-in-Mean model, for stock market return and trading volume. To overcome this difficulty, we adopt a sequential approach in order to estimate return-volatility links (as in Davidian and Carroll (1987) and Bessembinder and Seguin (1993)). First of all, we filter the volume series in order to take account of the endogeneity of volume with respect to return and volatility (Gallant et al. (1992)).

---

[1] Research Department, Bank of France. The views expressed in this paper are those of the authors and do not necessarily represent those of the Bank of France.

This paper analyses the links between stock market return, volatility and trading volume. This framework is used to study the daily returns of the reference stock market indices of the G5 countries over the period 1988–98. The model is composed of three equations (for volume, return and volatility), in which the aforementioned effects are introduced. To measure the effect of lagged variables, we also included a sequence of lags for all explanatory variables except trading volumes.

The remainder of the paper is organised as follows. Section 2 presents our model and the estimation methodology. Section 3 describes the data and outlines adjustments made to the data. Section 4 provides our main empirical results. Section 5 offers concluding remarks.

2. Methodology

2.1 The model

The model proposed in this paper generalises previous models, in particular those proposed by Hamao et al. (1990) or Bessembinder and Seguin (1993). It is written in the following form:

(1) $$\Delta I_t = A(L)\varepsilon_{t-1} + B(L)\Delta R_t + C(L)\sigma_t + Q_1\hat{v}_t + FD_t + m + \varepsilon_t$$

(2) $$\sigma_t = \alpha(L)\sigma_{t-1} + \beta(L)\varepsilon_{t-1} + \gamma\hat{v}_t + \varphi D_t + \sigma_0 + \eta_t$$

where $A(L)$, $B(L)$, $C(L)$, $\alpha(L)$ and $\beta(L)$ are lag polynomial matrices with $\alpha(L) = \sum_{i=0}^{p}\alpha_i L^i$. ΔI_t is the vector of returns of stock market indices at time t, where I_t denotes the index price in logarithm. ε_t is the vector of innovations of the process ΔI_t ($\varepsilon_t = \Delta I_t - E_{t-1}\,\Delta I_t$). Conditionally on the information set available at time t, ε_t is assumed to be normally distributed. ΔR_t is the vector of changes in the 10-year rates. σ_t is the vector of conditional volatilities of returns. η_t is the vector of innovations of σ_t. $\hat{v}_t$ is the vector of trading volumes.

The vector $D_t = (J_{1t},...,J_{4t},H_{t-1},H_{t+1},dum_{1t},...,dum_{Kt})$' groups all 0-1 variables: 'day' variables (J_{jt}, j=1,...,4) are equal to 1 on the given day in the week (Monday,..., Thursday), and 0 otherwise; the 'holiday' variable (H_t) is equal to 1 when date t is a holiday, and 0 otherwise; $\{dum_{kt}\}_{k=1,...,K}$ groups the dummy variables for major shocks on the stock markets.[2]

To allow for the current domestic interest rate and current domestic volatility in the return equation, but to exclude contemporaneous foreign variables, we introduce the following additional constraints: $B_{ij}(0)=C_{ij}(0)=0$, for all $i \neq j$.

Return equation (1) has the following features:

- The return of the country i index at time t is a function of past unexpected returns in that market and in other markets. Actually returns in all stock market indices are not introduced into equations for all stock returns. In fact, we apply a predefined ranking of countries by financial market size: US variables are systematically introduced to explain other stock market indices; German variables are systematically introduced into equations for other European stock market indices.[3]

[2] Dummy variables used are consistent across markets. They capture the main exogenous events that affected the international environment: the fall of the Berlin Wall (October 1989), German reunification (October 1990), the Gulf war (April 1990), and the attempted putsch in Moscow (1991). Because of time zone differences, the variables may sometimes have a one-day lag.

[3] The ranking of European markets recognises Germany as the European leader. This choice is based on the relative sizes of the national economies, rather than on the relative weight as financial markets. Assuming the United Kingdom as driving European markets does not improve our results.

To ensure consistency with the volatility equation, unexpected returns – rather than total returns – are introduced as explanatory variables.[4]

- The return of the country *i* index depends on changes in bond yields (present and past yields in country *i* and past yields in the driving foreign countries). Introducing long-term interest rates allows us to evaluate the impact of other variables – in particular, trading volumes and volatilities – independently of the strong direct effect of interest rates. Interest rates are undoubtedly the strongest explanatory variables for stock returns, and omitting this effect would bias the estimates of other effects. Besides, given the relative weights of bond and stock markets, long-term rates appear to be exogenous with respect to parameters of stock return equations.
- The return of the country *i* index is a function of present and past volatilities in that market, and past volatilities in the driving foreign markets. Engle et al. (1987) have shown the role of volatility as a risk-proxy variable in modelling returns. Volatility is introduced into the return equation systematically with past unexpected returns.
- The influence of domestic trading volumes in the return equation is measured in two ways: the log of unexpected trading volume; and a breakdown between positive and negative unexpected volume, allowing measurement of asymmetric effects on return and volatility equations.

The main features of the volatility equation (2) are the following:

- The volatility of the country *i* index at time *t* is a function of past volatilities in that market and in driving foreign markets.
- Introducing unexpected returns makes it possible to measure the possible asymmetry of return shocks on volatility.
- The influence of volumes in the volatility equation is tested under the same alternative forms as in the return equation: the unexpected volume, and the unexpected volume broken down into positive and negative shocks.

2.2 Estimating unexpected trading volumes

A large number of papers have shown the central role played by trading volumes in explaining the dynamics of stock market indices. Theoretical arguments have been proposed in order to introduce volumes into the return equation (Karpoff (1987)) and into the volatility equation (Epps and Epps (1976) and Admati and Pfleiderer (1988)). Trading volumes can be interestingly interpreted in terms of market "depth". Kyle (1985) defined market depth as the unexpected order flow required to move the stock market index by 1%. This definition is also chosen by Bessembinder and Seguin (1993) in their study of the impact of volume on volatility.

However, trading volume is strongly endogenous with respect to return and volatility. But the joint estimation of price equations (i.e. return and volatility) and of volume equations would be rather difficult due to the complexity of our specifications. One commonly adopted solution (Gallant et al. (1992), Bessembinder and Seguin (1993) and Campbell et al. (1993)) consists in filtering the volume series beforehand. This preliminary step also allows total volume to be broken down into expected volume and unexpected volume.

---

4 Accordingly, if countries are ranked in the following order (United States, Japan Germany, France and United Kingdom), matrices A_i, B_i, C_i, i=1,...,p, in equation (1) as well as α_i and β_i, i=1,...,p, in equation (2) have the following structure:

$$\begin{bmatrix} x & 0 & 0 & 0 & 0 \\ x & x & 0 & 0 & 0 \\ x & x & 0 & 0 & 0 \\ x & 0 & x & x & 0 \\ x & 0 & x & 0 & x \end{bmatrix}$$

For France, for example, this allows the presence of US, German and French variables in return and volatility equations.

Trading volume is broken down in two steps:

First, systematic effects (deterministic trend, day-of-the-week effects and holiday effects) are extracted from trading volume:

$$\text{(3)} \qquad \log V_{it} = \alpha + \beta t + \gamma t^2 + \sum_{j=1}^{4} f_j J_j + f_5 H_{it-1} + f_6 H_{it+1} + v_{it}$$

Second, the non-systematic trading volume, $\hat{v}_{it}$, is then broken down into an expected and an unexpected part. Some authors (including Gallant et al. (1992)) have identified a significant correlation between past volatility and trading volume, largely responsible for the endogeneity of volume with respect to price index. $\hat{v}_{it}$ is therefore regressed on its lagged values, on past volatility, and on past return. Volatility is defined here as the absolute value of the stock return ($s_{it} = |\Delta I_{it}|\sqrt{\pi/2}$). Therefore, we estimate the following regression:

$$\text{(4)} \qquad \hat{v}_{it} = \alpha + \sum_{j=1}^{4} \lambda_j \hat{v}_{it-j} + \sum_{j=1}^{4} \pi_j s_{it-j} + \sum_{j=1}^{4} \psi_j \Delta I_{it-j} + v_{it}^{na}$$

In what follows, the unexpected volume is defined as the estimated residual from the second step $\hat{v}_{it}^{na}$. This breakdown is based on the idea that market participants react differently to a shock on volume, depending on whether this shock is expected. More precisely, it may be that only unexpected volume affects return and volatility. In the following, we consider two ways of introducing unexpected volume. In the first model, we introduce unexpected volume directly; in the second model, we allow for an asymmetric effect of volume on both return and volatility equations.

2.3 Estimating the model

Given the large number of parameters to be estimated in return and volatility equations, it would appear very difficult to estimate this model using a direct maximum-likelihood approach. To overcome this problem, we follow the methodology proposed by Schwert (1990) and Bessembinder and Seguin (1993). First, as suggested by Schwert and Seguin (1990), volatility is estimated as:

$$\text{(5)} \qquad \hat{\sigma}_t = |\hat{\varepsilon}_t|\sqrt{\pi/2}$$

where $\hat{\varepsilon}_t$ is the estimated residual of the return equation. This definition is based on the result that $E(|x|) = \sigma\sqrt{2/\pi}$ if $x \to N(0, \sigma^2)$.[5] Volatility therefore depends on both unexpected returns and the absolute value of unexpected returns. A shock on the unexpected return will affect volatility in a different way, depending on whether the shock is positive or negative, according to the following relation:

$$\text{(6)} \qquad \frac{\partial \hat{\sigma}_{it}}{\partial \hat{\varepsilon}_{jt-l}} = \begin{cases} \beta_{ijl} + \alpha_{ijl}\sqrt{\pi/2} & \text{if} \quad \hat{\varepsilon}_{jt-l} > 0 \\ -\beta_{ijl} + \alpha_{ijl}\sqrt{\pi/2} & \text{if} \quad \hat{\varepsilon}_{jt-l} < 0. \end{cases}$$

Second, the econometric estimation of the model is carried out using the convergent sequential estimation method proposed by Davidian and Carroll (1987):

1. A return equation is first estimated by replacing domestic unexpected returns observed returns but without domestic and foreign volatilities. Moreover, the vector of past unexpected returns (denoted

---

[5] Other volatility indicators may be used. The standard deviation of the return-equation residuals over n trading days is one of the indicators most widely used by traders, but it is largely unsatisfactory because it implies an overlapping bias. Using implied volatilities would also have been an interesting alternative but, owing to the lack of adequate data, we were unable to implement it.

$\hat{\varepsilon}_{t-1}^{(0)}$) is composed of foreign unexpected returns and domestic observed return:

$$\Delta I_{it} = A_i(L)\hat{\varepsilon}_{t-1}^{(0)} + B_i(L)\Delta R_t + Q_{i1}\hat{v}_{it}^{na} + F_i D_t + m_i + \varepsilon_{it}^{(1)}$$

from which one obtains unexpected returns $\hat{\varepsilon}_t^{(1)}$.

2. Volatility is then computed using equation (3)

$$\hat{\sigma}_{it}^{(1)} = \left|\hat{\varepsilon}_{it}^{(1)}\right|\sqrt{\pi/2}$$

and a preliminary estimation of the volatility equation is performed: volatility is regressed on past domestic and foreign volatilities and on past domestic and foreign unexpected returns (the unexpected domestic return is the residual of the first-step regression):

$$\hat{\sigma}_{it}^{(1)} = \alpha_i(L)\hat{\sigma}_{t-1}^{(1)} + \beta_i(L)\hat{\varepsilon}_{t-1}^{(1)} + \gamma_i\hat{v}_{it}^{na} + \varphi_i D_t + \sigma_{i0} + \eta_{it}^{(1)}$$

from which one obtains expected volatilities $\hat{\sigma}_t^{(2)} = \hat{\sigma}_t^{(1)} - \hat{\eta}_t^{(1)}$

3. Return equation (1) is finally estimated, with domestic and foreign expected volatilities and domestic and foreign unexpected returns:

$$\Delta I_{it} = A_i(L)\hat{\varepsilon}_{t-1}^{(1)} + B_i(L)\Delta R_t + C_i(L)\hat{\sigma}_t^{(2)} + Q_{i1}\hat{v}_{it}^{na} + F_i D_t + m_i + \varepsilon_{it}^{(2)}$$

from which one obtains unexpected returns $\hat{\varepsilon}_t^{(2)}$.

4. Volatility is calculated once again as

$$\hat{\sigma}_t^{(3)} = \left|\hat{\varepsilon}_t^{(2)}\right|\sqrt{\pi/2}$$

and the volatility equation (2) is finally estimated:

$$\hat{\sigma}_{it}^{(3)} = \alpha_i(L)\hat{\sigma}_{t-1}^{(3)} + \beta_i(L)\hat{\varepsilon}_{t-1}^{(2)} + \gamma_i\hat{v}_{it}^{na} + \varphi_i D_t + \sigma_{i0} + \eta_{it}^{(2)}.$$

This sequential estimation method requires the variance-covariance matrix of residuals to be diagonal. The covariance between errors associated with the return equation (ε_t) and volatility equation (η_t) is assumed to be zero. However, volatility is allowed to have an instantaneous effect on return. Similarly, correlations between errors associated with different markets (ε_{it} and ε_{jt} for return equations, η_{it} and η_{jt} for volatility equations) are assumed to be zero. This constraint, however, is relaxed by the introduction into return and volatility equations of the most recent errors on other stock markets.

3. Data and preliminary analysis

3.1 Data

The data used in this paper are leading G5 stock market indices (Dow Jones in New York, DAX in Frankfurt, CAC 40 in Paris, FTSE 100 in London and Nikkei in Tokyo),[6] trading volumes for each market, and 10-year benchmark interest rates. The database has a daily frequency over the period from 1 January 1988 to 31 December 1998 (2,870 observations), recorded at the close of each trading day (source: Datastream). The choice of 1988 as the first year in our sample is intended to eliminate the October 1987 crash, which greatly disturbed stock markets.

[6] The stock market indices used are not necessarily consistent with one another: there are differences in methods used for weighting individual stocks and in the portion of total market capitalisation captured by each index. Nevertheless, these indices have been chosen because they are the most widely used indicators of aggregate prices in the different markets.

As far as trading volumes are concerned, we face two problems: first, reported trading volume is the number of securities traded during the session in the United States, Japan and the United Kingdom, but it is expressed in monetary units in Germany and France. Statistics on the number of securities traded are also available for German and French markets, but for a too short period to be used here. Second, some data had to be adjusted before any statistical analysis. In some cases, volumes were stated for holidays, trading days were left blank, and some entries were clearly aberrant. For the entire database, we corrected four observations in the United States, four in Germany, 21 in France, two in the United Kingdom, and four in Japan.

Opening and closing times of stock markets are reported in GMT in Datastream. If the market closes during the afternoon of day t in Europe, it closes during the morning of day t in Japan and during the evening of day t-1 in the United States.[7]

Non-trading days were treated as follows:[8]

When day t-1 is closed on the market examined, the variables of day t in change form (log of the index or interest rate) are defined as the change between two trading days (irrespective of the number of non-trading days between them); variables stated in levels (trading volume, volatility) are not adjusted since they are provided only for trading days; foreign variables in the domestic index equation are adjusted in the following way: first, if day t is a non-trading day for the foreign market, the foreign variables in change form are set to zero, and the variables in levels are assigned the value of the previous day; second, if day t is a trading day, we use the observed variations and levels.

If day t is a trading day for the market studied, but a non-trading day for the foreign market, foreign variables in change form are set to zero, and variables in levels are assigned the value of the previous day.

3.2 Preliminary analysis

Table 1 reports summary statistics on stock returns, trading volumes and 10-year interest rates in the G5 countries over the period under study. Stock returns exhibit an asymmetric distribution (negative in the United States, Germany and France; positive in the United Kingdom and Japan) and have significant fat tails (Table 1a). The excess kurtosis is rather high, from 2.3 for the FTSE 100 to 10.4 for the DAX. The Jarque-Bera test therefore rejects the normality hypothesis for each return series. The Ljung-Box statistics for serial correlation (LBQ, calculated with 20 lags) give mixed results since the null hypothesis of no serial correlation is rejected for the FTSE 100 and the Nikkei, but not for other stock market indices. Finally, the Ljung-Box statistics on the squared returns (LBQ2) indicate strong heteroskedasticity for all series. The statistical properties of the return series therefore require a specific model for stock returns and their volatility – at least as regards to the strong dependence of squared returns.

Concerning 10-year interest rates, normality is rejected for each country (Table 1b). The null hypothesis of no serial correlation is accepted only for French rates only. Besides, all interest rates exhibit significant serial correlation of squared returns.

As regards the growth rate of trading volume, we reject the hypothesis of normality, but not the hypothesis that the residuals are serially correlated, and homoskedasticity (Table 1c).

---

[7] There is a large overlap between European market opening times. In the case of the link between Frankfurt and Paris, for instance, introducing the current German return into the French return equation could be misleading: a significant effect of the German return may be interpreted as a causal link, whereas it may actually reflect a "news" effect only. To preclude this potential source of bias, we have estimated two types of models: in the first, we introduce lagged German variables only (in both French and UK equations, Tables 3 and 4); in the second, we introduce current German variables. Moreover, it is worth noting that New York opens after the closing of Frankfurt but before the closing of Paris. Thus the CAC 40 closing price may reflect some information from first transactions of New York that cannot be reflected in the closing price of DAX.

[8] The number of non-trading days differs considerably between countries. Over the period studied (1988–98), we identified 88 non-trading days in the United States, 116 in Germany, 129 in France, 89 in the United Kingdom, and 155 in Japan.

Table 1a
Statistics for stock returns

	Dow Jones	Nikkei	DAX	CAC 40	FTSE 100
Mean (%)	0.056	–0.017	0.058	0.051	0.045
Std dev. (%)	0.907	1.429	1.248	1.197	0.873
Skewness	–0.700 [a]	0.328 [a]	–0.871 [a]	–0.185 [a]	0.028 [a]
Kurtosis	7.565 [a]	4.843 [a]	10.440 [a]	2.812 [a]	2.309 [a]
Jarque-Bera	4,614.100 [a]	3,307.700 [a]	21,375.000 [a]	726.300 [a]	391.400 [a]
LBQ(20)	35.000 [b]	48.380 [a]	30.920 [c]	34.420 [b]	61.960 [a]
LBQ2(20)	253.390 [a]	617.110 [a]	295.330 [a]	601.730 [a]	922.550 [a]

Table 1b
Statistics for changes of 10-year rates

	United States	Japan	Germany	France	United Kingdom
Mean (%)	–0.002	–0.001	–0.001	–0.002	–0.002
Std dev. (%)	0.059	0.046	0.047	0.057	0.067
Skewness	0.236 [a]	0.209 [a]	0.658 [a]	–0.018	–0.292 [a]
Kurtosis	2.866 [a]	6.172 [a]	5.013 [a]	2.682 [a]	5.473 [a]
Jarque-Bera	523.700 [a]	2,737.600 [a]	1,927.000 [a]	533.100 [a]	2,821.000 [a]
LBQ(20)	43.540 [a]	30.780 [c]	43.960 [c]	17.860	34.220 [b]
LBQ2(20)	89.990 [a]	122.770 [a]	403.250 [a]	398.790 [a]	172.710 [a]

Table 1c
Statistics on trading volumes (rate of change)

	New York	Tokyo	Frankfurt	Paris	London
Mean (%)	0.049	–0.054	0.076	–0.014	0.012
Std dev. (%)	20.303	30.437	24.277	30.872	22.295
Skewness	–0.179 [a]	–0.092 [a]	0.032	0.047	–0.103 [b]
Kurtosis	6.099 [a]	1.847 [a]	1.924 [a]	2.745 [a]	2.480 [a]
Jarque-Bera	1,972.800 [a]	235.200 [a]	1,783.400 [a]	437.950 [a]	251.300 [a]
LBQ(20)	615.600 [a]	817.770 [a]	358.270 [a]	437.950 [a]	769.530 [a]
LBQ2(20)	350.500 [a]	174.700 [a]	176.890 [a]	425.790 [a]	118.580 [a]

Note: *a*, *b* and *c* indicate that the statistics are significant at a 1%, 5% and 10% level respectively. Under the null of normality, the Jarque-Bera statistics are chi-square distributed with 2 degrees of freedom. LBQ are the Ljung-Box statistics (computed with 20 lags) for the residuals; LBQ2 are the Ljung-Box statistics for the squared residuals; under the null of no correlation of the series considered, these statistics are chi-square distributed with 20 degrees of freedom.

Another issue concerns stationarity of the variables (Table 2). Stock-market indices (in log) and interest rates can be considered as difference-stationary processes. Indeed, autoregressive coefficients of variables in levels are very close to 1 and DF and ADF tests do not reject the null hypothesis of non-stationarity. On the other hand, variables in change form appear to be stationary. Furthermore, we find no evidence of non-stationarity for trading volumes. In all cases, volumes display a deterministic – not a stochastic – trend. Therefore, in what follows, trading volumes are treated as stationary around a deterministic trend.

Table 2
Non-stationarity tests

	Variable in level				Variable in change form			
	DF test		ADF test		DF test		ADF test	
	ϕ	t-stat	ϕ	t-stat	ϕ	t-stat	ϕ	t-stat
Stock market index								
Dow Jones	–0.004	–2.23	–0.003	–1.90	–0.988	–52.00	–1.111	–11.74
Nikkei	–0.002	–1.77	–0.002	–1.75	–0.991	–52.13	–0.980	–10.89
Dax	–0.003	–2.15	–0.004	–2.51	–0.950	–49.72	–0.996	–11.73
CAC 40	–0.005	–2.65	–0.006	–3.00	–0.921	–48.51	–0.909	–10.90
FTSE 100	–0.005	–2.95	–0.005	–2.70	–1.000	–51.98	–1.033	–11.42
Interest rate								
United States	–0.004	–2.31	–0.005	–2.81	–0.937	–49.54	–0.878	–10.27
Japan	–0.001	–1.47	–0.002	–1.75	–0.965	–50.61	–0.875	–10.76
Germany	–0.002	–1.63	–0.003	–2.03	–0.997	–52.13	–0.929	–11.28
France	–0.002	–1.74	–0.003	–1.99	–0.953	–50.01	–0.942	–11.37
United Kingdom	–0.002	–2.30	–0.003	–2.76	–0.970	–50.41	–0.737	–9.48
Trading volume								
New York	–0.400	–27.60	–0.115	–5.83	–	–	–	–
Tokyo	–0.186	–16.94	–0.060	–4.62	–	–	–	–
Frankfurt	–0.275	–20.94	–0.054	–3.52	–	–	–	–
Paris	–0.341	–24.66	–0.128	–6.47	–	–	–	–
London	–0.150	–15.05	–0.050	–4.38	–	–	–	–

Note: For each series, the change in variable is regressed on the one-period lagged level, a constant, a linear trend, dummy variables representing the day-in-week and the presence of a holiday the following or previous day, and, for the augmented Dickey-Fuller test, the 20 most recent changes. The estimated equation has the following form:

$$\Delta X_t = \alpha + \beta t + \phi X_{t-1} + \sum_{i=1}^{20} \theta_i \Delta X_{t-i} + \sum_{i=1}^{4} f_i J_i + f_5 H_{t-1} + f_6 H_{t+1} + \varepsilon_t$$

4. Empirical results

Estimations of model (1)-(2) are reported in Tables 3a and 3b using unexpected trading volume and Tables 4a and 4b allowing for asymmetric effects of volume. All estimations are performed with 5 lags for all explanatory variables in equations (1) and (2) (except for trading volumes, for which only the instantaneous effect is allowed). The model was also estimated with 10 lags, but the results are qualitatively the same, due to the weak significance of the higher-order lags.

When they are introduced in a given equation, foreign volatilities and foreign unexpected returns always refer to an already closed market. While this lag assumption does not raise any problems for the Dow Jones, it is clearly open to greater criticism in the case of interactions between European markets, which are open simultaneously and therefore react to the same news. In this case, the effect of contemporaneous foreign variables cannot be interpreted as a causal link, since it includes some reactions to common news. We therefore introduce only lagged German variables in French and UK equations. We also tested the influence of contemporaneous German variables on the CAC 40 index and the FTSE 100 to examine whether the influence of the other variables in the model is significantly modified. However, the results are not reported in this paper for space reasons. Obviously, in this case, the DAX index has a preponderant impact on the other European exchanges. For instance, the CAC 40 has a response of 5.5% and 3% for a shock of 10% in the DAX and the DJ respectively. But the importance of this effect should not be overestimated, since it also reflects the impact of international news on the other European markets.

4.1 Determinants of stock market return

4.1.1 Transmission between instruments and between countries

Two types of transmission are involved here: first between bond and equity markets, and second between markets in different countries. Let us first consider the model in which unexpected trading volume is introduced in return and volatility equations without asymmetric effects (Table 3).

The effect of bond yields on stock returns is particularly strong in all countries but Japan. The semi-elasticity ranges from –0.003 for the Nikkei (in which case it is not significant) to –0.095 for the CAC 40 index.

As regards transmission between stock markets, the first feature concerns the very strong influence of the Dow Jones on all other indices: everything else being equal, a 10% increase in the Dow Jones unexpected return causes a 3.5% increase in the Nikkei and 4.5% in the DAX. The influence of the DJ is slightly smaller on French and UK markets (2.3% and 2.7% respectively). Lagged Frankfurt stock return seems to have basically no impact on French and UK markets.

Table 3a

Estimation of model (1)-(2), return equation (with unexpected trading volume)

	Dow Jones	Nikkei	DAX	CAC 40	FTSE 100
Unexp. return – US	–	0.342	0.456	0.229	0.267
(sum of the 5 lags)		4.537	7.616	3.406	5.049
10-year rate – US	–	–0.023	0.006	0.022	–0.001
(sum of the 5 lags)		–2.773	0.787	3.081	–0.257
Exp. volatility – US	–	–0.057	–0.021	–0.020	–0.116
(sum of the 5 lags)		–0.414	–0.268	–0.180	–0.969
Unexp. return – Germany	–	–	–	–0.098	0.046
(sum of the 5 lags)				–1.536	0.935
10-year rate – Germany	–	–	–	0.027	0.000
(sum of the 5 lags)				1.901	0.045
Exp. volatility – Germany	–	–	–	–0.058	0.027
(sum of the 5 lags)				–0.291	0.266
Unexp. return – domestic	–0.002	–0.120	–0.006	0.028	–0.187
(sum of the 5 lags)	–0.042	–1.398	–0.100	0.507	–3.271
10-year rate – domestic	–0.044	–0.003	–0.053	–0.095	–0.049
(sum of the 5 lags)	–4.113	–0.170	–3.448	–7.858	–6.163
Exp. volatility – domestic	0.182	–0.005	0.010	0.091	0.102
(sum of the 5 lags)	2.304	–0.039	0.094	0.323	0.503
Trading volume	–0.068	1.400	0.667	–0.080	0.373
(current)	–0.286	5.705	3.408	–0.779	3.342
R2	0.138	0.162	0.339	0.255	0.230
s.e.e.	0.827	1.308	1.001	1.025	0.764
Q	48.351	58.310	62.157	35.802	57.304
p-value	8.185	1.073	0.435	47.796	1.345

Note: Estimates of the intercept and dummies are not reproduced. t-statistics (in brackets) are corrected for heteroskedasticity and are calculated using the Newey-West (1987) procedure. Estimates reproduced in this table correspond to the third step of sequential estimation presented in Section 2, that is:

$$\Delta I_{it} = A_i(L)\hat{\varepsilon}^{(1)}_{t-1} + B_i(L)\Delta R_t + C_i(L)\hat{\sigma}^{(2)}_t + Q_{i1}\hat{v}^{na}_{it} + F_i D_t + m_i + \varepsilon^{(2)}_{it}$$

The influence of foreign bond yields is generally rather weak on domestic stock returns. Note, however, that the US interest rate seems to replace the Japanese long-term rate that has no significant effect on the Nikkei return equation.

4.1.2 Effects of volatility on return

Expected domestic volatility has no significant impact on domestic returns in any country. This result appears to conflict with the results obtained by French et al. (1987) on US data. More recent studies, however, have cast doubt on the robustness of the conclusions of those authors. Using the same methodology, Poon and Taylor (1992), for example, found no significant effect of volatility on returns; Hamao et al. (1990), in most of their estimations, also failed to find any significant impact of volatility.

In the framework of our study, this result could also be explained by the introduction of volumes into the return equation. Indeed, estimating model (1)-(2) without trading volume gives, for almost all indices, a significant effect of expected volatility (results are not reproduced here).

4.1.3 Volume effects

Volume effects are analysed in three stages: the unexpected volume effect on the return equation, the unexpected volume effect on the volatility equation, and the effect of allowing asymmetric effects in return and volatility equations.

Table 3b

Estimation of model (1)-(2), volatility equation (with unexpected trading volume)

	Dow Jones	Nikkei	DAX	CAC 40	FTSE 100
Exp. volatility – US	–	0.162	0.549	0.133	0.056
(sum of the 5 lags)		1.238	3.472	0.751	0.549
Unexp. return – US	–	–0.221	–0.173	–0.032	–0.025
(sum of the 5 lags)		–4.249	–3.505	–0.625	–0.681
Exp. volatility – Germany	–	–	–	0.519	0.303
(sum of the 5 lags)				6.234	4.355
Unexp. return – Germany	–	–	–	–0.074	–0.059
(sum of the 5 lags)				–1.452	–1.605
Exp. volatility – domestic	0.431	0.548	0.462	0.186	0.299
(sum of the 5 lags)	8.218	16.386	11.500	4.217	6.922
Unexp. return – domestic	–0.214	–0.197	–0.058	–0.071	–0.070
(sum of the 5 lags)	–4.361	–5.189	–1.324	–1.818	–1.308
Trading volume	1.240	1.036	0.958	0.250	0.337
(current)	8.735	7.720	10.596	3.905	4.136
R2	0.162	0.207	0.236	0.125	0.134
s.e.e.	0.669	1.008	0.761	0.791	0.584
Q	129.352	124.534	125.913	61.172	136.369
p-value	0.000	0.000	0.000	0.551	0.000

Note: Estimates of the intercept and of parameters associated to dummies are not reproduced here. t-statistics (in brackets) are corrected for heteroskedasticity and are calculated using the Newey-West (1987) procedure. Estimates reproduced in this table correspond to the third step of sequential estimation presented in Section 2, that is:

$$\hat{\sigma}_{it}^{(3)} = \alpha_i(L)\hat{\sigma}_{t-1}^{(3)} + \beta_i(L)\hat{\varepsilon}_{t-1}^{(2)} + \gamma_i\hat{v}_{it}^{na} + \varphi_i D_t + \sigma_{i0} + \eta_{it}^{(2)}$$

Unexpected volume has a significant positive effect on returns, with the exception of the DJ and the CAC 40 (Table 3a). In Japan, this effect is very strong, since a 1% increase in the volume causes, everything else being equal, a 1.4% increase in the Nikkei return. For the DAX and the FTSE 100 indices, responses of return are 0.7% and 0.35% respectively.

Allowing an asymmetric effect of unexpected volume on return shows that an unexpected increase in volume generally has a stronger effect on return than an unexpected decrease. If we consider markets for which unexpected volume has a significant effect on return, we note in Table 4a that, for these three markets (DAX, FTSE 100 and Nikkei), the effect of a positive shock is more than twice the effect of a negative shock. For example, a 1% unexpected increase in volume in Tokyo implies a 2% increase in return, whereas a 1% decrease in volume only leads to a 0.5% decrease in return.

Table 4a
Estimation of model (1)-(2), return equation
(with asymmetric unexpected trading volume)

	Dow Jones	Nikkei	DAX	CAC 40	FTSE 100
Unexp. return – US	–	0.342	0.451	0.227	0.274
(sum of the 5 lags)		4.673	7.915	3.572	5.073
10–year rate – US	–	–0.023	0.006	0.022	–0.001
(sum of the 5 lags)		–2.807	0.792	3.074	–0.178
Exp. Volatility – US	–	0.017	0.024	0.015	–0.060
(sum of the 5 lags)		0.124	0.336	0.146	–0.565
Unexp. return – Germany	–	–	–	–0.104	0.044
(sum of the 5 lags)				–1.643	0.898
10–year rate – Germany	–	–	–	0.027	0.001
(sum of the 5 lags)				1.909	0.094
Exp. Volatility – Germany	–	–	–	–0.015	0.026
(sum of the 5 lags)				–0.076	0.250
Unexp. return – domestic	–0.006	–0.133	–0.003	0.020	–0.194
(sum of the 5 lags)	–0.133	–1.525	–0.059	0.372	–3.387
10–year rate – domestic	–0.044	–0.005	–0.053	–0.095	–0.049
(sum of the 5 lags)	–4.129	–0.279	–3.369	–7.919	–6.161
Exp. Volatility – domestic	0.170	–0.041	–0.012	0.013	0.066
(sum of the 5 lags)	2.348	–0.351	–0.118	0.044	0.315
Trading volume	–0.027	2.074	0.924	0.146	0.629
(current)	–0.053	5.341	2.973	0.887	3.227
Trading volume	0.007	–0.507	–0.401	0.229	–0.106
(current)	0.043	–2.142	–1.853	1.616	–0.781
R2	0.138	0.166	0.342	0.256	0.230
s.e.e.	0.827	1.304	0.999	1.024	0.763
Q	48.972	58.873	62.827	34.816	56.193
p–value	7.316	0.944	0.370	52.479	1.718

Note: Estimates of the intercept and of parameters associated to dummies are not reproduced here. t-statistics (in brackets) are corrected for heteroskedasticity and are calculated using the Newey-West (1987) procedure. Estimates reproduced in this table correspond to the third step of sequential estimation presented in Section 2, that is:

$$\Delta I_{it} = A_i(L)\hat{\varepsilon}_{t-1}^{(1)} + B_i(L)\Delta R_t + C_i(L)\hat{\sigma}_t^{(2)} + Q_{i1}\hat{v}_{it}^{na} + F_i D_t + m_i + \varepsilon_{it}^{(2)} .$$

4.2 Determinants of stock market volatility

While volatility exhibits significant autoregressive dynamics, it is clearly stationary in all markets. The index with the most persistent volatility is the Nikkei, with a cumulated impact of 0.55 for the five lagged volatilities. For the other indices, the cumulated impact is between 0.18 and 0.46. However, in most previous studies (e.g. Hamao et al. (1990)), the conditional variance appears to be strongly autoregressive, or even non-stationary. This result may be linked to the method used for calculating the conditional variance.

Table 4b
Estimation of model (1)-(2), volatility equation
(with asymmetric unexpected trading volume)

	Dow Jones	Nikkei	DAX	CAC 40	FTSE 100
Exp. volatility – US	–	0.141	0.522	0.111	0.042
(sum of the 5 lags)		1.125	3.653	0.711	0.520
Unexp. return – US	–	–0.220	–0.168	–0.026	–0.029
(sum of the 5 lags)		–4.247	–3.347	–0.500	–0.792
Exp. volatility – Germany	–	–	–	0.532	0.304
(sum of the 5 lags)				6.346	4.463
Unexp. return – Germany	–	–	–	–0.076	–0.059
(sum of the 5 lags)				–1.476	–1.588
Exp. volatility – domestic	0.421	0.552	0.470	0.177	0.297
(sum of the 5 lags)	7.979	16.927	13.156	4.049	6.629
Unexp. return – domestic	–0.216	–0.194	–0.060	–0.074	–0.068
(sum of the 5 lags)	–4.367	–5.438	–1.372	–1.937	–1.283
Trading volume	2.033	1.629	1.292	0.263	0.343
(current)	6.476	6.820	7.685	2.274	2.656
Trading volume	–0.546	–0.400	–0.558	–0.206	–0.365
(current)	–4.376	–2.700	–4.042	–2.347	–2.727
R2	0.173	0.218	0.241	0.123	0.133
s.e.e.	0.665	1.000	0.760	0.791	0.584
Q	135.617	136.453	136.954	63.623	135.190
p-value	0.000	0.000	0.000	0.304	0.000

Note: Estimates of the intercept and of parameters associated to dummies are not reproduced here. t-statistics (in brackets) are corrected for heteroskedasticity and are calculated using the Newey-West (1987) procedure. Estimates reproduced in this table correspond to the third step of sequential estimation presented in Section 2, that is:

$$\hat{\sigma}_{it}^{(3)} = \alpha_i(L)\hat{\sigma}_{t-1}^{(3)} + \beta_i(L)\hat{\varepsilon}_{t-1}^{(2)} + \gamma_i\hat{v}_{it}^{na} + \varphi_i D_t + \sigma_{i0} + \eta_{it}^{(2)}$$

4.2.1 "Leverage" effects

In all equations, unexpected returns has a negative impact on volatility. This effect is strongly significant for the Dow Jones and the Nikkei. The reaction of volatility to a return shock appears to be largely asymmetric (Table 5): in the case of the Dow Jones, for example, a positive 10% shock increases volatility by only 3.2%, whereas a negative 10% shock increases volatility by 7.4%. This asymmetric behaviour also turns out to be significant for the Nikkei: volatility increases by 5.0% after a positive return shock and by 8.9% after a negative shock.

Table 5

Impact of a 1% return shock on volatility (from estimation of Table 3)

	Dow Jones	Nikkei	DAX	CAC 40	FTSE 100
Positive shock	0.32	0.51	0.16	0.30	0.50
Negative shock	0.74	0.64	0.29	0.45	0.89

Note: Figures reported in this figure measure the total effect on volatility of a 1% shock on all lagged domestic returns:

$$\frac{\partial \hat{\sigma}_{it}}{\partial \hat{\varepsilon}_{jt-l}} = \begin{cases} \beta_{ijl} + \alpha_{ijl}\sqrt{\pi/2} & \text{if} \quad \hat{\varepsilon}_{jt-l} > 0 \\ -\beta_{ijl} + \alpha_{ijl}\sqrt{\pi/2} & \text{if} \quad \hat{\varepsilon}_{jt-l} < 0 \end{cases}.$$

4.2.2 Volatility transmission

International volatility transmission gives contrasting results. The expected volatility of the Dow Jones has a positive effect on the volatility of other markets, but this effect is significant for the DAX index only: a 10% increase in the DJ volatility implies, everything else being equal, a 5.6% increase in the DAX volatility. Moreover, the US unexpected return has a strong negative effect on DAX and Nikkei volatility. Therefore a negative shock on the US market leads to a larger increase of German and Japan volatilities than a positive shock does.

As regards European markets, the CAC 40 and the FTSE 100 volatilities are significantly affected by the German market. Indeed, the DAX expected volatility has a strong positive effect, whereas the unexpected return has a weak negative effect. Once again, a negative shock on the German market implies a larger increase of French and UK volatilities than a positive shock does. We obtain such a result whether or not current German variables are introduced in the CAC 40 and FTSE 100 equations.

To conclude, it is worth noting that we obtain some asymmetric effects for all market volatilities.

4.2.3 Volume effects

The effect of unexpected volume on volatility is strongly significant for all indices (Table 3b): between 0.96 and 1.12 for the Dow Jones, the DAX and the Nikkei; between 0.23 and 0.34 for the CAC 40 and the FTSE 100. These results can be interpreted in terms of market depth (along the lines of Kyle (1985)): a 1% change in the index is obtained by an unexpected change in volume by 0.89% (1/1.124) for Dow Jones, 1.04% for the DAX, 4.24% for the CAC 40, 2.99% for the FTSE 100 and 0.99% for the Nikkei. The relative magnitudes are comparable to those found by Bessembinder and Seguin (1993) for exchange rates.

Besides, we obtain for the Dow Jones, the DAX and the Nikkei a strong asymmetric effect of volume on volatility. For these three indices a 1% increase in unexpected volume implies an increase of volatility by more than 1.3%. Conversely a 1% decrease in unexpected volume leads to a decrease of volatility by less than 0.6%.

To conclude, all stock market indices are affected in one way by volumes: unexpected volumes positively affect most returns and all volatilities. Asymmetric effects of volume on return and volatility are particularly strong in Japan and, to a lesser extent, Germany.

5. Conclusion

The model proposed in this paper provides a framework to measure different types of interdependence: the interactions between return and volatility for a given index, transmission mechanisms between stock markets for return as well as for volatility, and the effect of trading volumes on return and volatility.

Several findings are of interest.

First, interest rates are found to have a strong negative effect on all stock returns. All returns exhibit spillover effects from the New York stock exchange. The German index has basically no impact on French and UK indices at the return level. International transmission mechanisms are also strong for the volatility equation: US expected volatility and/or unexpected return have a clear-cut effect on the DAX and Nikkei volatility. In addition, German variables play a similar role for the CAC 40 and the FTSE 100. The Dow Jones does not seem to have a direct effect in terms of volatility on the French and UK markets.

Volatility is not found to play a significant role in explaining returns. This confirms the difficulty of detecting the presence of an ARCH-in-Mean effect in stock return equations. By contrast, asymmetric effects – i.e. the effect of unexpected return on volatility – are significant for the US and Japanese indices. Overall, there is some kind of asymmetry for each stock market. This effect can come from the domestic unexpected return (as in the US and Japan) or from foreign unexpected return (DAX, CAC 40, FTSE 100 and Nikkei). We can conclude that, for all stock markets, a negative shock (bad news) has a larger effect on the volatility than a positive shock (good news).

Finally, unexpected trading volume has a strong positive impact on all indices. In the return equation, this influence is more pronounced for the DAX, the FTSE 100 and the Nikkei. Moreover, all volatilities are strongly influenced by volume effects. Unexpected volume appears to have asymmetric effects on return as well as on volatility. A positive shock on volume affects German, UK and Japanese returns more strongly than a negative shock does. Similarly, a positive shock on volume affects US, German and Japanese volatility more strongly than a negative shock does.

Bibliography

Admati, A R and P Pfleiderer (1988): “Selling and Trading on Information in Financial Markets”. *American Economic Review*, 78(2), pp. 96-103.

Bessembinder, H and P J Seguin (1993): “Price Volatility, Trading Volume, and Market Depth: Evidence from Futures Markets”. *Journal of Financial and Quantitative Analysis*, 28, pp. 21-39.

Booth, G G, T Martikainen and Y Tse (1997): “Price and Volatility Spillovers in Scandinavian Stock Markets”. *Journal of Banking and Finance*, 21, pp. 811-23.

Campbell, J Y, S J Grossman and J Wang (1993): “Trading Volume and Serial Correlation on Stock Returns”. *Quarterly Journal of Economics*, 435, pp. 905-39.

Copeland, T E (1976): “A Model of Asset Trading under the Assumption of Sequential Information Arrival”. *Journal of Finance*, 31, pp. 1149-68.

Davidian, M, and R J Carroll (1987): “Variance Function Estimation”. *Journal of the American Statistical Association*, 82, pp. 1079-91.

Engle, R F, T Ito and W L Lin (1990): “Meteor Showers or Heat Waves?: Heteroskedastic Intra-Daily Volatility in the Foreign Exchange Market”. *Econometrica*, 58, pp. 525-42.

Engle, R F, R M Lilien and R P Robins (1987): “Estimating Time Varying Risk Premia in the Term Structure: The ARCH-M Model”. *Econometrica*, 55, pp. 391-407.

Epps, T W (1975): “Security Price Changes and Transaction Volumes: Theory and Evidence”. *American Economic Review*, 65, pp. 586-97.

Epps, T W and M L Epps (1976): “The Stochastic Dependence of Security Price Changes and Transaction Volumes: Implications for the Mixture-of-Distributions Hypothesis”. *Econometrica*, 44, pp. 305-21.

Eun, C and S Shim (1989): “International Transmission of Stock Market Movements”. *Journal of Financial and Quantitative Analysis*, 24, pp. 241-56.

Fama, E F (1965): “The Behavior of Stock Market Prices”. *Journal of Business*, 38, pp. 34-105.

French, K R, G W Schwert and R F Stambaugh (1987): “Expected Stock Returns and Volatility”. *Journal of Financial Economics*, 19, pp. 3-30.

Gallant, A R, P E Rossi and G Tauchen (1992): “Stock Prices and Volume”. *Review of Financial Studies*, 5, pp. 199-242.

Hamao, Y, R W Masulis and V Ng (1990): “Correlations in Price Changes and Volatility Across International Stock Markets”. *Review of Financial Studies*, 3, pp. 281-307.

Harris, L and E Gurel (1986): “Price and Volume Effects Associated with Changes in the S&P 500 List: New Evidence for the Existence of Price Pressures”. *Journal of Finance*, 41, pp. 815-29.

Jacobs, M and J Onochie (1998): “A Bivariate Generalized Autoregressive Conditional Heteroscedasticity-in-Mean Study of the Relationship between Return Variability and Trading Volume in International Futures Markets”. *Journal of Futures Markets*, 18(4), pp. 379-97.

Jennings, R H, L T Starks and J C Fellingham (1981): “An Equilibrium Model of Asset Trading with Sequential Information Arrival”. *Journal of Finance*, 36, pp. 143-61.

Karpoff, J M (1987): “The Relation between Price Changes and Trading Volume”. *Journal of Financial and Quantitative Analysis*, 22, pp. 109-26.

Karpoff, J M (1988): “Costly Short Sales and the Correlation of Returns with Volume”. *Journal of Financial Research*, 11, pp. 173-88.

Koutmos, G and G G Booth (1995): "Asymmetric Volatility Transmission in International Stock Markets". *Journal of International Money and Finance*, 14(6), pp. 747-62.

Kyle, A S (1985): "Continuous Auctions and Insider Trading". *Econometrica*, 53, pp. 1315-35.

Mandelbrot, B (1963): "The Variation of Certain Speculative Prices". *Journal of Business*, 36, pp. 394-19.

Newey, W K and K D West (1987): "A Simple, Positive Definite, Heteroscedasticity and Autocorrelation Consistent Covariance Matrix". *Econometrica*, 55, pp. 703-8.

Poon, S H and S J Taylor (1992): "Stock Returns and Volatility: An Empirical Study of the UK Stock Market". *Journal of Banking and Finance*, 16, pp. 37-59.

Schwert, G W (1989): "Why Does Stock Volatility Change Over Time?" *Journal of Finance*, 44, pp. 1115-54.

Schwert, G W (1990): "Stock Volatility and the Crash of '87". *Review of Financial Studies*, 3, pp. 77-102.

Schwert, G W and P J Seguin (1990): "Heteroskedasticity in Stock Returns". *Journal of Finance*, 45, pp. 1129-56.

Tauchen, G E and M Pitts (1983): "The Price Variability-Volume Relationship on Speculative Markets". *Econometrica*, 51, pp. 485-505.

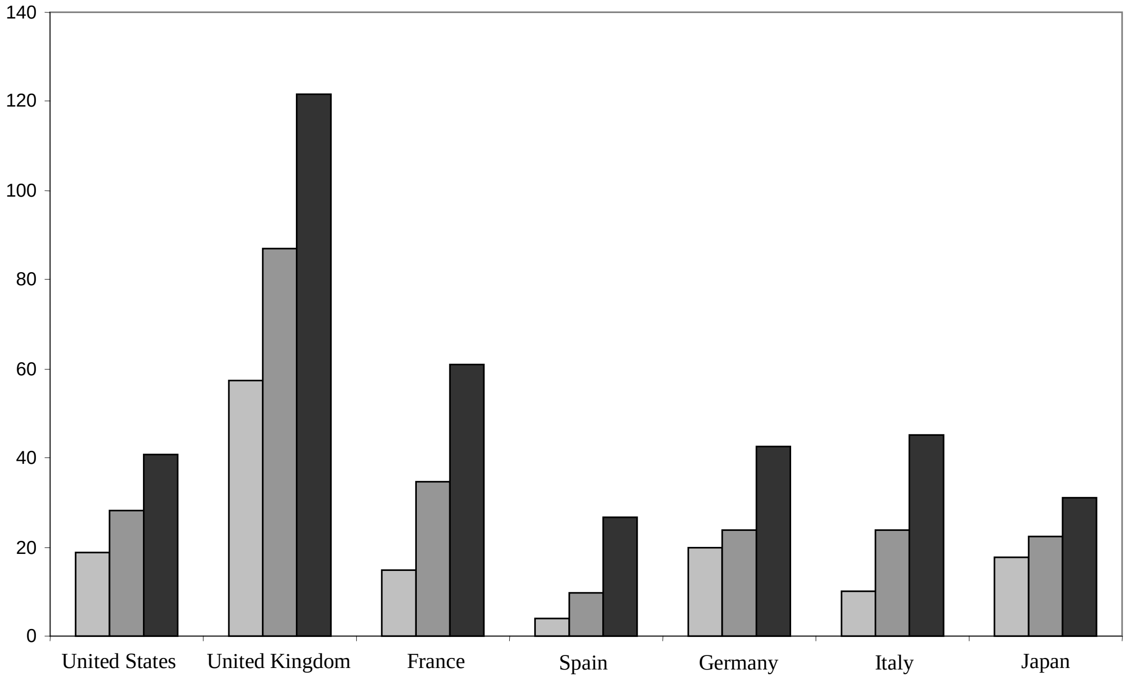
Has financial market integration increased during the 1990s?

Juan Ayuso and Roberto Blanco[1]

1. Introduction

Financial crises are not a new phenomenon. What seems to be new, however, is their increasing tendency to become worldwide. During the last few decades the widespread liberalisation of capital movements has fostered fierce competition among financial services providers while a parallel process of technological innovation has supplied the means to move huge capital amounts quickly and safely across borders. In this new framework, financial markets quite often provide examples of the well-known "butterfly effect", the easing of the Federal Reserve's monetary policy in response to the collapse of LTCM being, perhaps, one of the most recent. Furthermore, it is hardly debatable that the weight of foreign assets in agents' portfolios has markedly increased during the last few years – Chart 1 shows, for example, the rising path of the direct and portfolio investment abroad of selected countries. In these circumstances, it is argued that international integration among domestic financial markets has grown to such a point as to render them too vulnerable to relatively unimportant news. Nevertheless, a more thorough analysis seems to be needed before reaching such a conclusion.

Chart 1. Direct and portfolio investment abroad as a percentage of GDP



Sources: IMF; OECD.

Indeed, the evidence above only reveals that, at least to some extent, financial market linkages have increased. Yet closer linkages do not necessarily imply higher financial market integration – i.e. an

[1] We wish to thank Francisco Alonso for outstanding research assistance, and Enrique Alberola, José Luis Escrivá, Jorge Martínez and participants in the BIS meeting and in the internal seminar at the Bank of Spain for very helpful comments and suggestions.

additional removal of barriers of any kind to cross-border financial transactions. Thus, it could be argued that not only financial markets but also economies, as a whole, have reached a higher level of internationalisation. Cross-border commercial linkages have increased as well. Moreover, it should be borne in mind that the same technological innovations that have paved the way for cross-border financial transactions have also increased the worldwide diffusion of information in real time. Accordingly, it could be the case that the main driving force behind the apparent increase in financial market linkages is the globalisation of the news that affects financial prices instead of a higher degree of market integration.

In our view, it is important to determine whether there has been a genuine increase in financial market integration. It is worth noting that the assessment of a hypothetical increase in financial market linkages will depend on the causes of the increase. In terms of welfare, for example, it should be clear that whereas a removal of barriers implies an increase in diversification opportunities – thus reducing the levels of risk that agents have to accept to obtain a given return – a greater globalisation of the relevant information set would mean exactly the opposite. Similarly, the implications of each scenario regarding the need for a global supervisor would be different if information, instead of markets, is more global.

The main goal of this paper is to investigate whether there has been a genuine increase in the degree of financial market integration during the 1990s. To do this, we focus on stock markets and compute, first, a number of standard measures of financial market integration that, in our view, only measure financial market linkages. This allows us to make a more formal assessment of the actual increase in financial market linkages and, at the same time, the shortcomings of these measures as indicators of financial market integration become clearer. Second, we analyse whether there has been any notable advance in the degree of "pure" financial market integration by computing two alternative measures of market integration based on a refinement of the approach suggested in Chen and Knez (1995).

The paper is organised as follows. After this introduction, Section 2 computes standard measures of market linkages that reveal a higher degree of linkage but are unable to show whether this is due to higher market integration or to other factors. Section 3 addresses this question and computes direct measures of the changes in market integration during the 1990s that show an increasing degree of market integration over this decade. Finally, Section 4 summarises the main results and points out some of their potential policy implications.

2. Standard measures of linkages between international stock prices

Perhaps the simplest approach in the literature to analyse the degree of market integration is that based on the computation of the correlation between returns on those markets that are thought to be more integrated than previously.[2] This approach is based on rather simple intuition: the more integrated markets are, the higher the comovement between their prices. In this connection, Table 1 shows the correlation between weekly returns on seven selected stock exchanges (New York, London, Paris, Madrid, Frankfurt, Milan and Tokyo)[3] during the 1990–94 and 1995–99 periods. In 15 out of the 21 possible combinations, the correlation has increased in the second half of the 1990s, with the Japanese stock exchange accounting for the remaining six cases. On average, the correlation between the returns on these stock exchanges increased from 0.42 during the period 1990–94 to 0.54 during 1995–99.

Although this evidence can be considered as supporting the view of a higher degree of financial market linkages, it is well known that higher correlation is neither a necessary nor a sufficient

---

2 See, for example, Taylor and Tonks (1989) or Le (1991).

3 Returns have been obtained as the first difference of the logarithm of a representative index for each stock exchange: these are, respectively, S&P 500, FTSE All-Share, CAC 40, IGBM, DAX 30, MIB all shares and Nikkei 225. See the Annex for details about the data used.

condition for greater market integration.[4] If markets are completely integrated and, therefore, there are no arbitrage opportunities, returns on different assets can be divided into a common component and an idiosyncratic one. The latter, however, may be sufficiently important as to render ex post correlation rather low.

Table 1
Correlation between stock indices (weekly data)

	Between national stock exchanges											
	US		UK		France		Spain		Germany		Italy	
	I	II	I	II	I	II	I	II	I	II	I	II
UK	0.42	0.61										
France	0.39	0.60	0.58	0.70								
Spain	0.40	0.59	0.51	0.70	0.58	0.74						
Germany	0.29	0.58	0.53	0.70	0.62	0.74	0.52	0.74				
Italy	0.20	0.45	0.38	0.53	0.42	0.62	0.45	0.67	0.47	0.60		
Japan	0.34	0.33	0.37	0.32	0.34	0.32	0.46	0.30	0.31	0.28	0.24	0.23
	Between sectors within the US stock exchange											
	TECS		XF		HLTS		CPGS		ENRS		XU	
	I	II	I	II	I	II	I	II	I	II	I	II
XF	0.63	0.55										
HLTS	0.43	0.53	0.42	0.67								
CPGS	0.84	0.69	0.73	0.75	0.48	0.60						
ENRS	0.29	0.25	0.39	0.45	0.29	0.32	0.47	0.47				
XU	0.28	0.08	0.46	0.46	0.29	0.36	0.37	0.31	0.46	0.40		
XT	0.62	0.45	0.66	0.68	0.38	0.45	0.78	0.71	0.39	0.42	0.34	0.34

Note: See the Annex for a description of national and sectoral indices. Period I: 1990–94; period II: 1995–June 1999.

To illustrate this point, the bottom panel of Table 1 replicates the same exercise for seven selected sub-indices of the New York Stock Exchange. Although there are no reasons to think that this stock exchange was less self-integrated during the first half of the 1990s, 13 out of 21 correlations increased in 1995–99. Moreover, the average correlation between groups of shares within the NYSE in 1995–99 is 0.47, lower than the average correlation between the selected national stock exchanges during the same period. Given that it is not reasonable to think that the degree of market integration is higher across stock exchanges than within any of them, we have to conclude that this approach is flawed.

An alternative approach builds on the previous one and is aimed at measuring to what extent the returns on other markets can help to explain the returns on one particular market. Table 2 shows the main results of this approach, which consists here of a comparison between the (sum of squared) residuals of a simple univariate autoregressive model for each return and the (sum of squared) residuals of a VAR model for the seven returns considered. First of all, it has to be noted that the seven markets considered do not share common trading hours and consequently implications cannot be drawn from comparisons between countries within the same period.[5] Nevertheless, we are not interested in a comparison between countries within the same period but in a comparison of different periods for the same country. Yet there is no reason to think that the implications of the different trading hours – whatever they might be – have changed in the second half of the 1990s.

4 See, for example, Adler and Dumas (1983).

5 For example, the relatively low improvement ratio for the NYSE could be due to the fact that this is the stock exchange that closes the latest each day, thus being open to news that arrives when other stock exchanges are closed.

Table 2
The explanatory power of other market returns on the own market return (daily data)

Period		National stock indices						
		Japan	UK	Germany	France	Italy	Spain	US
I	SSR univ (1)	3,020.51	855.27	1,680.48	1,747.90	1,868.50	1,455.96	732.30
	SSR VAR (2)	2,840.19	779.88	1,480.46	1,625.46	1,730.57	1,366.60	719.86
	((1)–(2)) / (1)	5.97%	8.81%	11.90%	6.96%	7.38%	6.14%	1.70%
	No. of observ.				1,299			
	q				12			
II	SSR univ (1)	2,404.09	736.37	2,001.04	1,798.24	2,071.64	1,631.90	1,093.83
	SSR VAR (2)	2,174.19	624.65	1,494.08	1,611.14	1,519.17	1,480.80	1,073.12
	((1)–(2)) / (1)	9.56%	15.17%	25.33%	10.40%	26.67%	9.26%	1.89%
	No. of observ.				1,150			
	q				6			
		Sectoral indices						
		TECS	XF	HLTS	CPGS	ENRS	XU	XT
I	SSR univ (1)	1,330.51	1,404.80	1,614.32	929.67	982.95	902.14	1,431.88
	SSR VAR (2)	1,315.97	1,387.38	1,597.42	916.96	973.79	894.95	1,397.45
	((1)–(2)) / (1)	1.09%	1.24%	1.05%	1.37%	0.93%	0.80%	2.40%
	No. of observ.				1,299			
	q				6			
II	SSR univ (1)	3,133.84	2,066.84	1,804.60	1,306.17	1,705.21	688.91	1,556.00
	SSR VAR (2)	3,102.66	2,056.92	1,780.77	1,284.77	1,681.02	655.91	1,530.38
	((1)–(2)) / (1)	0.99%	0.48%	1.32%	1.64%	1.42%	4.79%	1.65%
	No. of observ.				1,150			
	q				6			

Note: See the Annex for a description of national and sectoral indices. Period I: 1990–94; period II: 1995–June 1999. q is the number of new regressors in the VAR when compared with the univariate model.

According to Table 2, during the first half of the 1990s the sum of the squared residuals is reduced, on average, by 6.98% when other market returns are taken into account to explain the behaviour of stock returns. During the second half of the decade, the reduction amounts to 14.04%, thus revealing a higher average degree of linkage between the markets considered. This increased linkage is, moreover, uniform across the seven countries and could even be underestimated in Table 2 given that the VAR approach adds only six parameters to each univariate model in the 1995–99 period whereas 12 parameters are added in the 1990–94 period.[6]

In order to evaluate the magnitude of the recorded increases in linkages, the bottom panel of Table 2 replicates the exercise for the same seven sub-indices of the NYSE as in Table 1, thus offering a useful yardstick. During the second half of the decade there is also an increase in the explanatory power of the other market returns. Nevertheless, this increase has three interesting features. First, it is clearly lower (1.27% compared to 1.76%) than that in the upper panel. Second, it is not uniform across sectors (only four out of seven show an improvement). And third, the levels of the reduction in the sum of squared residuals in each period are somewhat lower than those corresponding to the seven country case (1.27% and 1.76% versus 6.98% and 14.04%). Accordingly, it could be concluded that the increase in the linkages between the returns on the stock exchanges chosen is quite genuine.

[6] In 1990–94 the VAR model includes two lags, whereas in 1995–99 a single lag is sufficient to eliminate any residual autocorrelation. Accordingly, when compared to the univariate model, the VAR adds 12 more parameters (2 lags x 6 countries) during the first period and only six (1 lag x 6 countries) during the second.

Table 3
The explanatory power of other market returns (daily data without outliers)[1]

Period[3]		National stock indices[2]						
		Japan	UK	Germany	France	Italy	Spain	US
I	SSR univ (1)	2,723.84	769.00	1,303.07	1,467.97	1,692.66	1,134.29	454.20
	SSR VAR (2)	2,638.23	724.90	1,144.02	1,398.95	1,583.41	1,089.93	447.64
	((1)-(2)) / (1)	3.14%	5.73%	12.21%	4.70%	6.45%	3.91%	1.44%
	No. of observ.				1,299			
	q[4]				12			
II	SSR univ (1)	2,080.10	576.21	1,546.16	1,407.05	1,666.28	1,237.77	448.14
	SSR VAR (2)	2,000.96	551.72	1,366.82	1,349.81	1,480.42	1,181.02	446.00
	((1)-(2)) / (1)	3.80%	4.25%	11.60%	4.07%	11.15%	4.58%	0.48%
	No. of observ.				1,150			
	q[4]				6			
II[5]	SSR univ (1)	2,078.19	575.36	1,543.44	1,406.91	1,663.83	1,237.43	447.31
	SSR VAR (2)	1,985.25	545.60	1,348.10	1,324.52	1,461.51	1,167.71	444.64
	((1)-(2)) / (1)	4.47%	5.17%	12.66%	5.86%	12.16%	5.63%	0.60%
	No. of observ.				1,150			
	q[4]				12			

[1] Returns two standard deviations away from the average have been removed as explained in the main text. [2] See the Annex for a description of national and sectoral stock indices. [3] Period I: 1990–94; period II: 1995–June 1999. [4] q is the number of new regressors in the VAR model when compared with the univariate model. [5] The VAR model has been over-parameterised by including an additional lag.

To further investigate the nature of the recorded increases in linkages, another sort of robustness test is offered in Table 3. This table replicates the same exercise as Table 2 but with the largest outliers eliminated from the series. The idea behind this exercise is to test to what extent the previous results are due to the presence of a few large outliers that are common to all series – as, for example, when a sudden crisis emerges. Thus, days were selected in which at least one of the seven series showed returns two standard deviations away from its average. For each of these dates (160 in total, i.e. for 6.53% of the sample) a dummy variable taking the value 1 on that day and 0 otherwise was built. Finally, all these dummy variables were used as a common set of interventions. That is, each stock exchange return was regressed on all dummy variables and the residuals were taken as the new returns to perform the same exercise as in Table 2.

When outliers are removed, the sum of squared residuals is, on average, reduced even more sharply in 1995–99 than in 1990–94 (5.71% versus 5.37%). Regarding individual country data, however, only in three out of the seven possible cases is the reduction higher in the second half of the 1990s. Nevertheless, this comparison is to some extent flawed because, as commented above, in the first period the univariate models are enlarged with six more parameters than in the second period when the VAR model is estimated. This biases the results against the information content of other-market returns during 1995–99. To circumvent this problem, we over-parameterised the second period by including an additional lag in the VAR model. After this modification, the reduction in the sum of squared residuals is, on average, higher in 1995–99 (6.65% versus 5.37%) and affects five out of seven countries. When compared to Table 2, results in Table 3 are certainly less clear-cut but still point towards an increase in the linkages between stock prices.

Nevertheless, it is not possible in this case either to draw any firm conclusion from the apparent higher financial market linkages on the changes in the degree of financial market integration. As a matter of fact, there are cases in which a lower predictive power of other market returns might be reflecting a higher degree of market integration. Thus, for example, it could be argued that if information flows efficiently, any relevant news – i.e. disregarding idiosyncratic shocks – would be immediately absorbed by all prices quoted on any market. Accordingly, in a model like the VAR estimated above, other market (lagged) returns should not contain any relevant information provided that the own market (lagged) returns are taken into account. From this standpoint, the results in Tables 2 and 3 might even be seen as pointing towards less efficiency in the transmission of information – i.e. greater barriers to financial trade and therefore less integration.

Tables 1 to 3 address the issue of market linkages by focusing on stock return levels. Nevertheless, there are also other statistical moments that could be analysed to elicit further relevant information on the relationships between financial markets. In particular, it is also of interest to analyse whether there is greater linkage between stock price volatilities. In Engle et al. (1988), volatility linkages are explored to draw conclusions on market efficiency from the way information arrives in financial markets and is transmitted between them.

As is well known, the question of how volatility should be measured has received an almost unanimous answer in the literature: by estimating the conditional variance of the series considered. There are, however, several models available to make such an estimate.[7] In this paper, we estimate the model proposed in Glosten, Jagannathan and Runkle (GJR) (1989). This model consists of a small but highly significant variation to the GARCH model proposed by Bollerslev (1986) which allows it to capture an important feature of stock returns: the leverage or asymmetric effect first noted by Black (1976). The importance of this innovation is highlighted in Engle and Ng (1993), who perform an interesting horse race between several conditional variance models to explain the behaviour of the conditional variance of Japanese stock returns and conclude that "the best model is the one proposed by Glosten, Jagannathan and Runkle".

In this paper, we first estimate a GJR model for each of the residual series of the VAR model. These models are next enlarged to include the lagged (squared) residuals corresponding to the remaining markets as new explanatory variables. In particular, as we are interested in testing whether the role of the other market residuals has increased, we include as new regressors each other market (squared) residual and the product of each other market (squared) residual times a step dummy variable which takes the value 1 during the period 1995–99 and 0 otherwise. Consequently, a positive and significant value of the coefficient of the latter would imply an increasing role of the corresponding other market volatility to explain the volatility of the own market.

Formally,

$$(1) \qquad h_{i,t} = a_0 + \sum_{k=1}^{q1} a_k e_{i,t-k}^2 + \sum_{k=1}^{q1} g_k e_{i,t-k}^2 S_{i,t-k}^- + \sum_{k=1}^{q2} b_k h_{i,t-k} + \sum_{j \neq i} \left(\sum_{k=1}^{q1} d_{j,k} e_{j,t-k}^2 + \sum_{k=1}^{q1} dd_{j,k} e_{j,t-k}^2 SS_{t-k} \right)$$

where

$e_{i,t} = r_i - E_{t-1}(r_{i,t})$; $e_{i,t} \mid \Omega_{t-1} \sim N(0, h_{i,t})$ and $E_{t-1}(r_{i,t})$ – i.e. the conditional expectation on $r_{i,t}$ – is computed from the VAR model,

i, j = Japan (JP), the United Kingdom (GB), Germany (DE), France (FR), Italy (IT), Spain (ES) and the United States (US),

$S_{i,t}^- = 1$ if $e_{i,t} = 1 \leq 0$ and 0 otherwise,

$SS_t = 1$ from 1995 to 1999 and 0 otherwise.

It is worth noting that the VAR model includes the levels of the other market returns as explanatory variables for each own market return. Accordingly, the possibility can be ruled out that squared residuals from other markets appear as significant in the conditional variance equation only as a consequence of (level) residuals being an omitted variable in the conditional mean equation.

Table 4 shows the main results of the exercise. First of all, it has to be noted that the GJR models fit reasonably well, as shown by the standard goodness-of-fit tests reported in the table (CH1, CH5, T1, T2 and T3). The leverage effect – that is, the coefficient g_1 – is also important in all but one country.

[7] See, for example, Engle and Ng (1993) for an extensive comparison among alternative methods.

Regarding volatility linkages, however, the picture emerging from Table 4 is rather less clear-cut than that regarding the linkages between return levels.

Table 4
Glosten-Jagannathan-Runkle conditional variance models[1]

$$h_{i,t} = a_0 + \sum_{k=1}^{q1} g_k e_{i,t-k}^2 S_{i,t-k}^{-} \sum_{k=1}^{q2} b_k h_{i,t-k} + \sum_{j \neq i} \left(\sum_{k=1}^{q3} d_{j,k} e_{j,t-k}^2 + \sum_{k=1}^{q3} dd_{j,k} e_{j,t-k}^2 SS_{t-k} \right)$$

where i, j = JP, GB, DE, FR, IT, ES, US; $e_{i,t}$ are the residuals of the VAR model; $S_{i,t}$ = 1 if $e_{i,t}$ is negative and SS_t = 1 since 1995

	Japan		UK		Germany		France		Italy		Spain		US	
a_0(se)	0.03	(.01)	0.32	(.01)	0.01	(.00)	0.08	(.02)	0.07	(.01)	0.06	(.01)	0.01	(.00)
a_1(se)	0.02	(.001)	0.15	(.02)	0.02	(.00)	–		0.05	(.01)	–		0.02	(.01)
a_2(se)	–		0.12	(.02)	–		–		–		–		–	
b_1(se)	0.90	(.01)	–		0.94	(.01)	0.84	(.02)	0.85		0.81	(.02)	0.90	(.01)
g_1(se)	0.12	(.01)	–		0.04	(.01)	0.08	(.01)	0.04	(.02)	0.07	(.02)	0.08	(.01)
$d_{1,\text{JAP}}$			0.008	(.004)	–		0.007	(.003)	–		0.007	(.003)	–	
$dd_{1,\text{JAP}}$	–		–		–		–		–		–		–	
$d_{1,\text{UK}}$	–		–		–		–		–		–		–	
$dd_{1,\text{UK}}$	–		–		–		–		–		–		0.02	(.01)
$d_{1,\text{GER}}$	–		–		–		–		–		–		–	
$dd_{1,\text{GER}}$	0.013	(.006)	0.06	(.01)	–		0.02	(.01)	–		0.08	(.01)	–	
$d_{1,\text{FRA}}$	–		0.06	(.01)	–		–		–		0.03	(.01)	–	
$dd_{1,\text{FRA}}$	–		–0.06	(.01)	–		–		–		–0.03	(.01)	–	
$d_{1,\text{ITA}}$	–		–		–		–		–		0.02	(.01)	–	
$dd_{1,\text{ITA}}$	0.008	(.003)	–		–		–		–		–0.02	(.01)	–	
$d_{1,\text{SPA}}$	–		–		–		0.03	(.01)	0.03	(.01)	–		0.007	(.002)
$dd_{1,\text{SPA}}$	–		–		–		–		–		–		–	
$d_{1,\text{USA}}$	–		–		0.03	(.01)	–		–		–		–	
$dd_{1,\text{USA}}$	–		–		–0.02	(.01)	–		–		–		–	
CH1[2]	0.21		1.54		0.89		0.02		0.97		0.27		1.17	
CH5[2]	0.78		3.47		1.44		9.64		1.69		0.61		1.68	
T1[3]	–0.09		–0.84		1.76		–1.80		–0.10		2.45		0.01	
T2[3]	–0.54		–0.35		0.63		–1.12		0.83		1.62		–0.78	
T3[3]	–0.10		0.65		–0.43		–0.10		–1.33		–1.88		0.03	
Obs.							2,452							

[1] See the Annex for a description of national and sectoral stock indices. [2] CH1 and CH5 are, respectively, tests for residual conditional variance up to orders 1 and 5. Under the null (no residual variance) their distribution is chi-squared with 1 and 5 degrees of freedom. [3] T1, T2 and T3 are, respectively, the sign, positive bias and negative bias tests in Engle and Ng (1993). Under the null (no residual asymmetry and no positive or negative non-linearity) they obey a Student-t distribution.

In general, the estimated coefficients suggest that, compared to the weight of the innovations in the own market, other market variability does not play an important role in explaining each own market conditional variance. When the first and the second half of the 1990s are compared, in three cases (Japan, France and the United States) other market squared residuals account for a higher part of the own-market volatility during the 1995–99 period. In Italy, there are no significant changes during the 1990s. In another case (Germany) the role of other market residuals is lower during the second half of the decade. And finally, there are two cases (the United Kingdom and Spain) in which there seems to have been a simple change of protagonist. Thus, for example, UK volatility was more sensitive to the variability in France during the first half of the decade whereas during the second half Germany was the main source of additional volatility.

Thus, once the effects of other market return levels are used to explain the level of returns in each market, the evidence in Table 4 does not offer clear support to the view of an increasing volatility linkage during the 1990s. Nevertheless, it has to be borne in mind that, as commented above, a more prominent role of innovations in a market to explain the volatility of other market returns might be interpreted as a sign of informational inefficiency. Accordingly, the evidence in Table 4 could also be seen, at least to some extent, as a sign of a high degree of market integration.

All in all, the results in this section seem to give mild support to the existence of an increase in stock market linkages, which is clearer in the case of levels than in that of volatility. Nevertheless, it remains to be seen whether these greater linkages are the consequence of a genuine higher degree of market integration or merely reflect the greater globalisation of the main sources of the news which drives stock prices. Addressing this question is the main goal of the rest of this paper.

3. Measuring financial market integration

3.1 Conceptual framework

Perfect cross-market integration is generally understood as a situation in which there is no barrier of any kind to cross-border financial transactions, such as tariffs, taxes, restrictions on the trading of foreign assets, information costs or any other cost that makes it more difficult to trade across countries than within them. With perfect cross-market integration there are no cross-market arbitrage opportunities and the law of one price – i.e. portfolios with the same payoffs should have the same price in different markets – holds. It is worth noting, however, that, as suggested above, the law of one price or the absence of arbitrage opportunities cannot be assessed from the analysis of the comovement of the levels of financial asset prices or of their volatilities.

Although this point can be made without reference to any specific asset pricing model, it is easier to illustrate it if a particular model is considered. Thus, for the sake of simplicity, let us assume that assets are priced according to the well-known APT model. Under this model each (ex post) asset price is equal to the sum of the products of a number of random factors (the sources of risk) multiplied by their coefficients (generally called risk prices) plus the realisation of an idiosyncratic shock. If markets are perfectly integrated these random factors have to be equally priced in each market. Accordingly, an increase in the degree of integration between markets that were previously segmented should increase the comovements of their prices due to the reduction in the differences between the prices of the common risk factors. Nevertheless, increases in the comovements may also be the result of a greater intersection of the sets of risk factors affecting prices in both markets – possibly as a result of a greater globalisation of news – while differences in the risk prices remain. Similarly, a reduction of the weight of the idiosyncratic shocks would also result in a higher (ex post) comovement independently of the degree of market integration.

Against this background, Chen and Knez (1995) developed a measurement theory of market integration that relies directly on the concept of the law of one price and the condition of absence of arbitrage opportunities and does not depend on any particular asset pricing model.[8] Following the seminal work of Hansen and Jagannathan (1991, 1997), the measures they proposed exploit certain properties of the stochastic discount factors. The latter are random variables *d*, which are implicitly defined in the following unconditional moment restriction:

(2) $$E(p_i) = E(x_i d) \quad \forall i \in N$$

[8] In the literature other approaches that test for integration based on the notion of absence of arbitrage have been developed (for instance, Adler and Dumas (1983) use an international CAPM). However, as pointed out by Chen and Knez (1995), the main shortcoming of these approaches is that any test of market integration is, at the same time, a test of the particular asset pricing model used.

where $E(.)$ is the expectation operator, p_i is the price of asset i, x_i is the future payoff of that asset,[9] and N is the number of assets traded in the market studied. Expression (2) is derived by applying the law of iterated expectations to the equilibrium condition of a generic asset pricing model: prices of a future payoff on any traded security have to be equal to the expected product of the payoff and the intertemporal marginal rate of substitution.[10] All random variables d satisfying equation (2) make up the family of admissible stochastic discount factors. It is found that under certain conditions the pricing structure of a market can be completely summarised by these discount factors.

Chen and Knez (1995) showed that the law of one price holds across two markets if and only if the intersection between their sets of admissible stochastic discount factors is not empty.[11] Based on this result, they proposed to measure the degree of market integration as the (square of the) minimum square distance between the sets of the admissible stochastic discount factors in the two markets.[12] Note that this measure is zero if and only if the two markets are perfectly integrated. A strictly positive value for this measure indicates the degree of segmentation: the lower the measure, the more closely integrated the two markets. Applying a result taken from Hansen and Jagannathan (1997),[13] this measure can be interpreted as the maximum (squared) difference between the prices assigned by two markets to any unit-norm common payoff.[14] Thus, this measure reflects the magnitude of pricing discrepancy between the two markets and, to some extent, indicates the minimum costs necessary to prevent investors from taking advantage of the pricing discrepancy.

In order to implement the measure empirically, Chen and Knez (1995) proposed to use data on prices and payoffs for a sample of securities in two markets and to approximate population moments with sample moments. Formally, the set of admissible discount factors d in market j – D_j – is made up of any vectors of dimension T – the number of time series observations – that satisfy the following N_j restrictions.[15]

$$OP_j = dX_j \tag{3}$$

where O is a vector of ones with dimension T, P_j is the matrix of the prices of the N_j securities traded in market j and X_j is the matrix of the payoffs of the same securities.

It is worth noting that the value of the estimated integration measure depends on the combination of the values chosen for T and $N_A + N_B$. In particular, it is straightforward to show that if T is higher than $N_A + N_B$ and the rank of X_{A+B} is $N_A + N_B$ [16] – i.e. two portfolios with equal payoffs, one from each market, cannot be constructed – the intersection between D_A and D_B will be non-empty because the system resulting from jointly considering (3) in both markets does have a solution. In this case the estimated integration measure will always be equal to zero. Note that in this situation cross-market arbitrage is not possible because we cannot form two portfolios with the same payoffs in both markets,

---

9 This model assumes the existence of only two periods. In the first one, assets are traded; in the second, investors obtain the payoffs.

10 This is the so-called Euler equation, which is common to all existing asset pricing models. Particular models differ in the specification of consumers' preferences and, therefore, of the marginal rate of substitution.

11 They also proved that cross-market arbitrage opportunities do not exist if and only if the intersection between the sets of non-negative admissible stochastic discount factors is not empty.

12 They called this the weak integration measure. They also proposed another measure – the strong integration measure – which computes the same distance when only the non-negative elements of those sets are taken into account.

13 Hansen and Jagannathan (1997) showed that the least square distance between a random variable and the set of admissible stochastic discount factors of one particular market gives the maximum pricing error in using that random variable to price any unit-norm payoffs traded on that market.

14 The strong integration measure can be interpreted as the mini-max bound on the (squared) pricing differences when using the non-negative stochastic discount factors of the two markets to price any conceivable unit-norm payoff.

15 These restrictions are the sample counterparts of the population restrictions of expression (2).

16 In our data set this tends to occur in (almost) all cases.

not because both portfolios are equally priced. Thus, under these circumstances, the integration measure will be uninformative.[17]

Two lessons can be drawn from the previous comments. First, when implementing the integration measure, attention has to be paid to the selection of T, N_A and N_B. Second, the absolute value of the integration measure is difficult to interpret. In other words, it would be preferable to use it in comparing pairs of markets or periods.

In this paper, we apply the methodology described above to assess how market integration has changed during the 1990s. More specifically, we compute two different integration measures – both based on this theory – for pairs of markets in the period 1990–94 and compare them with those obtained for the period 1995–99. To undertake this exercise we use daily data on prices and payoffs[18] denominated in US dollars for a sample of securities traded in three out of the seven stock exchanges considered in Section 2 – New York, Frankfurt and Madrid.

Unfortunately, in our data set the aggregate number of securities in any pair of markets is much lower than the number of time series observations in each of the periods studied. In order to avoid the uninformative solution mentioned above, we followed two alternative approaches. Under the first one, we compute the (square root of the) integration measure proposed by Chen and Knez (1995) using only monthly data, which leaves us with only 53 observations in each period.[19] This figure is lower than the total available number of assets on the US stock exchange, which overcomes the trivial solution. The problem with this approach is, first, that we lose some of the available information. Also, it should be recognised that this is a "tricky" approach since we force data to guarantee the existence of two portfolios – one from each market – with common payoffs. In fact, both portfolios might have different payoffs if we considered more periods.

The second approach relies on weekly data, which gives us 230 observations in each period. In this case, the problem of getting an uninformative zero value is overcome by computing mean distances between the sets of admissible discount factors instead of minimum distances. Of course, the mean distance between two sets could be strictly positive even if they do intersect.[20] Note that this measure has a different pricing error interpretation as it computes the mean – instead of the minimum – of the maximum absolute pricing errors when using the pricing rules implied by one market to price any unit-norm payoffs marketed on the other market.[21] Thus, this measure could be interpreted as the expected maximum pricing discrepancy between two markets.

Alternatively, the latter measure can be interpreted in terms of the expected minimum distance between the sets of discount factors in markets A and B (D_A and D_B) when expanding these markets to include all assets traded. To see this, note first that the higher the number of assets, the more reduced the size of the sets D_A and D_B. Nevertheless, given that information is always limited these sets will tend to be too large and we will find a non-empty intersection – and, therefore, a zero minimum distance. Yet in this case we can still distinguish between cases like those in Chart 2. In general, as the information set expands and sets D_A and D_B reduce, the minimum distance will tend to increase. If it becomes finally non-negative, it can be expected to be higher in the left-hand situation. That is, the higher the mean distance between D_A and D_B, the higher the expected minimum distance, provided the

---

[17] Chen and Knez (1995) estimated the degree of integration between the NASDAQ and the NYSE computing their integration measures, but they did not take into account this observation. The estimated figures they obtained are very low but non-zero probably as a result of the algorithm they applied, which cannot produce a zero value as it stops when convergence is supposed to be reached.

[18] The payoffs are computed taking into account splits, dividends and capital increases in addition to capital gains – i.e. price changes. See the Annex for more details about the data used.

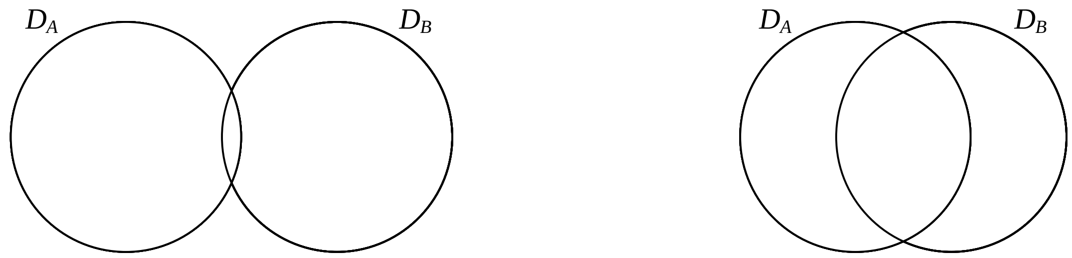
[19] The number of observations in the first period (1990–94) is higher than 53, but we have reduced the size to 53 in order to make the comparison between the periods fairer, given that, as we have shown, the sample size could affect the results.

[20] To be more precise, as will be clear later, we introduce some restrictions that affect the value of the discount factors in order to simplify computation and to guarantee the existence of the mean.

[21] This interpretation follows after applying the result of Hansen and Jagannathan (1997). See footnote 13.

information set is large enough. Or put in a different way, the lower the mean distance, the higher the probability of having a non-empty intersection when the information set is large enough.

Chart 2. Mean distance between sets of admissible discount factors as a measure of integration



Low degree of integration High degree of integration

The procedure we followed to implement the two integration measures introduced in the previous paragraphs has two important features. First, for each of the three markets studied we form a number of sub-markets by taking different samples of assets, each one having its associated set of admissible discount factors. This allows us to have – in each period – a set of integration measures, instead of point estimates, which varies according to the particular stocks included in each sub-market. Second, we not only estimate the integration measures between different markets, but we also estimate them within the same market[22] – the benchmark market. This allows us to have values of the integration measure for a market which is thought to be self-integrated. By construction these figures will generally be strictly positive in spite of the fact that the market is perfectly self-integrated. So, we can have a set of values for the measures which could be used as reference values for perfectly integrated markets. Thus, the relative measures of integration – defined as the difference between the absolute integration measure between two different markets and that within the benchmark market – will be easier to interpret as integration measures – i.e. a significant positive value for this relative measure will suggest that markets are not perfectly integrated.

More specifically, the procedure we followed involves – in both approaches and in each period – the following five steps:

i) One market is taken as a benchmark.

ii) A random group of N_A securities is selected from among the assets available in the benchmark market. In what follows, this group of assets will be referred to as sub-market *A* and D_A will stand for the set of discount factors that price assets in that sub-market.

iii) 100 random combinations of groups of N_B securities are selected in each of the three markets studied. In what follows, any of these groups of assets will be referred to as sub-market *B*, and D_B will stand for the set of discount factors that price assets in those sub-markets. So, we have 300 sub-markets *B* – 100 sub-markets for each of the three markets. For the benchmark market, stocks in sub-markets *B* are restricted to being different to those selected in step ii).

iv) Distances[23] between the fixed set D_A and the sets D_B are computed. So, we get 100 distances for each of the three pairs of markets. These 100 distances are then averaged for each pair of markets. Thus, we finally have 3 average distances.

v) Steps ii) to iv) are repeated 100 times.

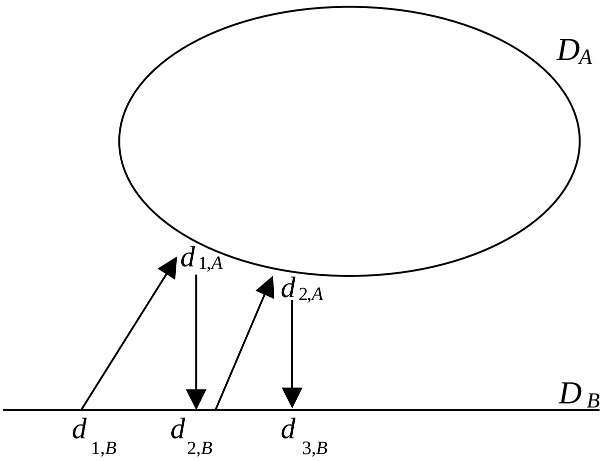
---

[22] In other words, in this case sub-markets *A* and *B* are made up of stocks belonging to the same market.

[23] Under the first approach the minimum distances are computed, and under the second approach mean distances are computed.

The distances computed in step iv) are estimated using the two different algorithms described next – one for the first approach and another for the second one. The integration measure of the first approach – i.e. the minimum distance between sub-markets A and B – is estimated following the algorithm proposed by Chen and Knez (1995). The logic behind it is depicted in Chart 3. This algorithm involves two iterative steps. In the first step, the least square projection of a selected point in D_B onto the set D_A is computed. The square distance between those points in sets D_B and D_A is also recorded. In the second step, the least square projection of the point found in D_A onto the set D_B and the square distance between both points are computed. These iterative steps are repeated until the distance converges. As the first point in D_B in the iteration process we take the least square projection of a vector of ones onto the set D_B.

Chart 3. Illustration of algorithm 1



D_A and D_B are, respectively, the set of stochastic discount factors for sub-markets A and B. $d_{1,B}$ is the point in D_B used in the first iteration and $d_{1,A}$ is its least square projection onto D_A. Similarly, $d_{2,B}$ is the least square projection of $d_{1,A}$ onto D_B, $d_{2,A}$ is the least square projection of $d_{2,B}$ onto D_A and $d_{3,B}$ is the least square projection of $d_{2,A}$ onto D_B.

The algorithm used to estimate the second integration measure – i.e. the mean distance between sub-markets A and B – computes the least square distance between random points in D_B and the set D_A. This estimation is repeated for different points in D_B and the mean of the found distances is computed until convergence is reached. The points in D_B are taken as the least square projection of a vector whose components are randomly drawn from a uniform distribution defined in the interval (0.5-1.5).[24] This procedure guarantees the existence of a finite mean and simplifies the computation.

The iteration process in both algorithms stops once the sum of absolute changes in the estimated distance measure for the last five iterations is less than 0.05 basis points.[25] Least square distances and least square projections are estimated using the following expressions:[26]

(4) $$\delta_j = \left[\left(\frac{1}{T}(dX_j - OP_j) \right) \left(\frac{1}{T}(X_j' X_j) \right)^{-1} \left(\frac{1}{T}(dX_j - OP_j) \right)' \right]^{1/2}$$

[24] As a consequence, we would expect the elements of the points selected in D_B not to be too far away from this interval.

[25] This stopping rule is similar to that suggested in Chen and Knez (1995).

[26] These expressions are the sample counterparts of those found by Hansen and Jagannathan (1997), which are derived after solving the optimisation problem involved.

(5) $$d_j' = d' - X_j\left(\frac{1}{T}(X_j' X_j)\right)^{-1}\left(\frac{1}{T}(dX_j - OP_j)\right)'$$

where δ_j is the least square distance between a vector *d* and the set D_j, and d_j is the least square projection of one vector *d* onto the set D_j.

3.2 Results

Table 5 shows the main results under the first approach – minimum distances between pairs of sets of discount factors – when the US market is used as the benchmark[27] and the number of assets in sub-markets *A* and *B* is, respectively, 44 and 10. In these conditions, the number of time series observations – 53 – is lower than the total number of assets in both sub-markets, but higher than the number of assets considered in each sub-market. Thus, we force an empty intersection between sets D_A and D_B provided the combined payoffs matrix has a rank of 54. More specifically, the table shows some descriptive statistics of the 100 averages of the minimum distances between the sets of discount factors of sub-markets *A* and *B* for three different pairs of markets for the 1990–95 and 1995–99 periods.

Table 5
Minimum distances, in basis points, between sets of stochastic discount factors, with the United States as the benchmark

	1990–94			1995–99		
	US-US	US-DE	US-ES	US-US	US-DE	US-ES
Mean	111.7	160.5	180.8	88.6	92.0	111.7
Minimum	75.0	76.1	108.9	60.2	48.0	75.3
Maximum	173.5	252.5	279.2	152.7	172.5	231.7
Standard deviations	21.3	35.6	32.0	18.0	24.9	27.2
Average no. of iterations	3,618.5	4,126.7	3,924.1	2,828.5	2,656.3	3,016.3

Note: The table shows, for each period and pair of markets, some summary statistics of 100 averages of the estimations of the minimum distances between the sets of discount factors in sub-markets *A* and *B*. Each average is computed for a fixed set D_A and 100 different sets D_B. D_A and D_B are, respectively, the sets of admissible discount factors in sub-markets *A* and *B*, and are defined as the discount factors that price stocks belonging to sub-markets *A* and *B*. Sub-market *A* is a sample of 44 stocks quoted in the benchmark market and sub-market *B* is a sample of 10 stocks quoted in the other market of the pair.

Two important features emerge from Table 5. First, irrespective of the period considered, the mean of the minimum distance is lower for the pair US-US than for any other pair. This is a reasonable result that suggests a higher degree of market integration within the US market than between this market and either of the other two. Second, the mean of the minimum distance between every pair of markets is lower in 1995–99 than in 1990–95, suggesting an increase in the degree of integration in the second half of the decade. However, the same trend, although to a lesser extent, could be observed regarding the integration within the US market. This development may be explained by sample errors, which seem to be relatively important as suggested by the values of standard deviations.

As commented in Section 3.1, relative instead of absolute distances probably offer a clearer picture of the developments in the degree of market integration during the 1990s. These measures are defined, for every replication, as the difference between the distance between pairs of sets associated with stocks traded in different markets and the distance computed with pairs of sets that price stocks in the benchmark market. Table 6 reports the main results of this exercise and Chart 4 plots the

[27] Due to the small number of available assets in the data set corresponding to the other two markets we could not take them as benchmark markets.

corresponding histograms. According to Table 6, the mean minimum relative distance between markets has decreased during the second half of the decade. Chart 4 shows, moreover, that not only has the average decreased, but the empirical distributions of the relative distances have shifted to the left in the second period. All this suggests an increase in the degree of integration between different markets during the 1990s. Another interesting result is that the degree of integration between the Spanish and the US markets seems to be lower than that between the German and US markets in both periods considered.

Table 6
Relative minimum distances, in basis points, between sets of stochastic discount factors, with the United States as the benchmark

	US-DE		US-ES	
	1990–94	1995–99	1990–94	1995–99
Mean	48.8	3.4	69.1	23.2
Minimum	–13.6	–32.8	9.2	–28.2
Maximum	130.4	66.1	152.6	86.1
Standard deviation	33.4	19.2	28.4	22.3
% positive	94.0	55.0	100.0	87.0

Note: The table shows, for each period and pair of markets, summary statistics of the 100 averages of estimations of the relative minimum distances between the sets of discount factors in sub-markets *A* and *B*. For the pair US-DE, the relative distance is calculated as the difference between averages of minimum distances when sub-markets *A* and *B* are made up, respectively, of stocks belonging to the US and German markets and averages of minimum distances when both sub-markets are made up of stocks belonging to the US market. Sub-market *A* is a sample of 44 stocks quoted on the benchmark market and sub-market *B* is a sample of 10 stocks quoted in the other market of the pair.

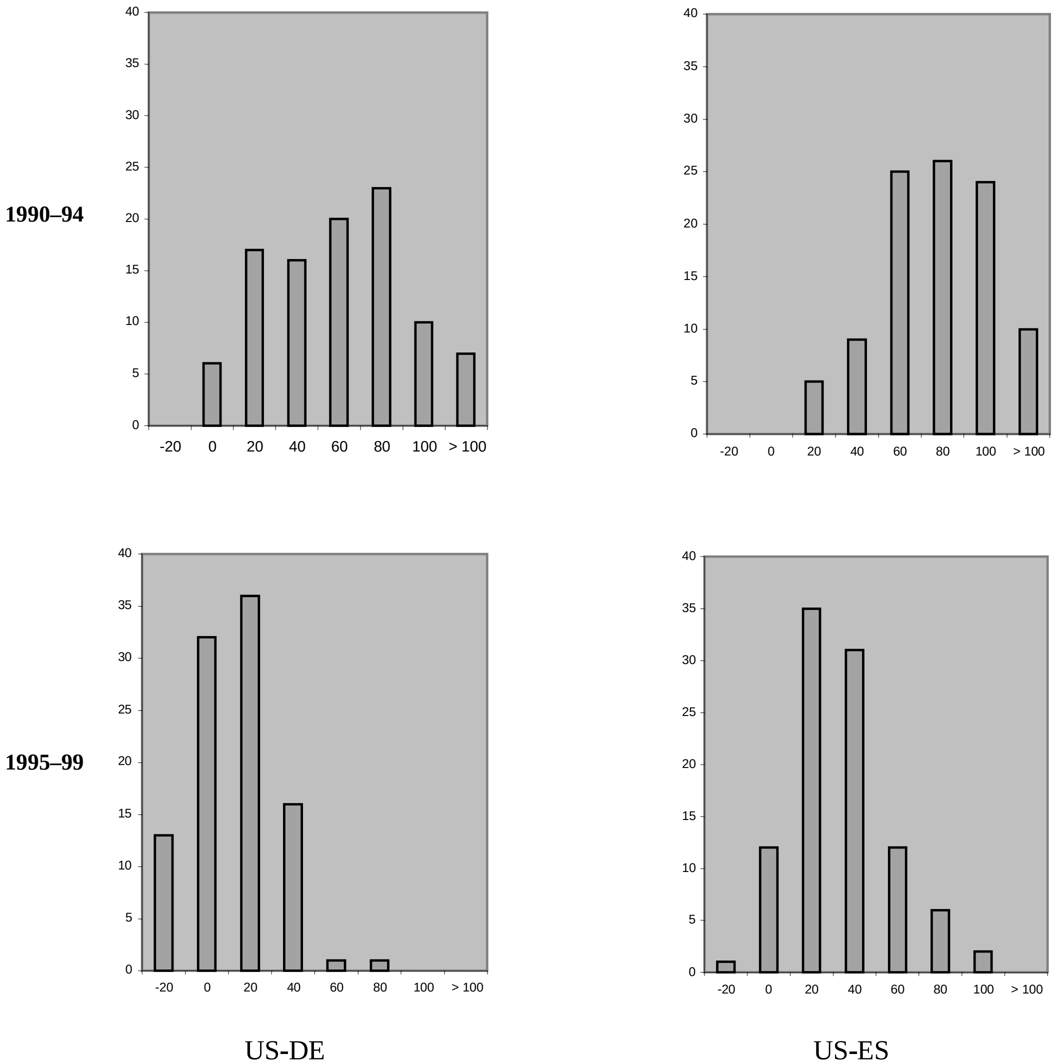
Regarding the second approach – mean distances between sets of discount factors – Table 7 gives the main results when the benchmark is the US market and the number of assets in both sub-markets is equal to 10. Apart from the statistics reported in Table 5, Table 7 also reports the results of the mean distances between the set of discount factors in the US market and a fixed set made up of all vectors whose components range between 0.5 and 1.5, which are used as a yardstick.

It is interesting to note that the two most prominent features of Table 5 are also present here. That is, first, the mean of the distances is lower in the pair US-US than in any other pair irrespective of the period considered, and second, the distances between pairs of different countries are lower in 1995–99 than in 1990–95. Interestingly, in this case the mean of the integration measure within the US stock exchange remains almost unchanged during the 1990s (it is only slightly higher during the second period). Also, the average of the mean distances between the fixed set and the set of discount factors for US assets is slightly higher during the second period.

Another interesting feature of the estimates resulting from the second approach is their low standard deviation compared with those obtained under the first approach. This possibly indicates that they are computed with a higher precision. Two different factors could explain the difference in precision: i) measures in the second approach are estimated with a larger data set, and ii) sample means are less sensitive to outliers than the sample minimum.

Table 8 shows the main results of the analysis when relative distances are considered and Chart 5 plots the corresponding histograms. The results of this analysis are similar to those reported under the first approach. First, empirical distributions of the relative distances shift to the left in the second period, suggesting an increase in the degree of integration between different markets during the second half of the decade. Conversely, the change in the distribution of the mean distance between the fixed set and the set of discount factors in the US market changes only slightly during the second period, the mean of the distribution being almost the same. Second, the degree of integration between the Spanish and US markets seems to be lower than that between the German and US markets in each of the periods considered.

Chart 4. Distribution of the relative minimum distances (in basis points) between sets of stochastic discount factors, with the United States as the benchmark



Note: See the note to Table 6 for an explanation.

Table 7
Mean distances (in basis points) between sets of stochastic discount factors, with the United States as the benchmark

	1990–94				1995–99			
	US-US	US-DE	US-ES	US-FIX	US-US	US-DE	US-ES	US-FIX
Mean	432.9	444.9	452.0	639.3	434.2	441.2	443.0	640.4
Minimum	403.2	413.0	424.3	609.6	404.7	402.4	410.1	606.8
Maximum	479.6	497.9	489.0	687.7	470.8	481.0	486.4	681.3
Standard deviation	15.2	18.8	13.7	15.6	15.0	17.4	15.5	16.4
Average no. of iterations	2,376.2	2,396.3	2,404.5	2,706.4	2,381.0	2,414.0	2,393.2	2,702.3

Note: The table shows, for each period and pair of markets, summary statistics of 100 averages of the estimations of the mean distances between the sets of discount factors in sub-markets *A* and *B*. Averages of mean distances are computed for a fixed set D_A and 100 different sets D_B. D_A and D_B are, respectively, the sets of admissible discount factors in sub-markets A and B, and are defined as the discount factors that price stocks belonging to sub-markets *A* and *B*. Sub-market *A* is a sample of 10 stocks quoted in the benchmark market and sub-market. *B* is a sample of 10 stocks quoted in the other market of the pair. In the pair US-FIX, D_B is the set formed by all vectors whose components range between 0.5 and 1.5. This distance is used as a yardstick.

Table 8
Relative mean distances (in basis points) between sets of stochastic discount factors, with the United States as the benchmark

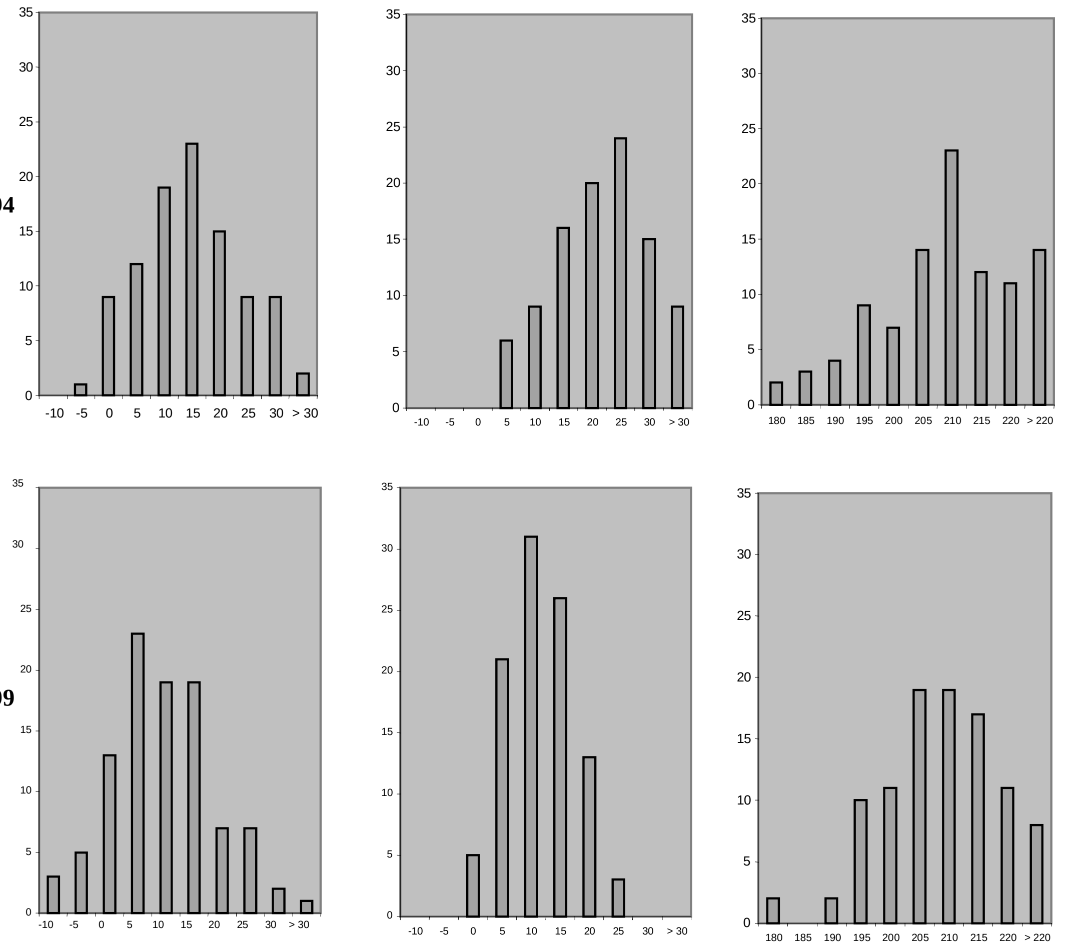
	US-DE		US-ES		USA-FIX	
	1990–94	1995–99	1990–94	1995–99	1990–94	1995–99
Mean	12.0	7.0	19.1	8.8	206.4	206.2
Minimum	–9.2	–21.9	0.7	–3.3	177.9	169.9
Maximum	39.2	30.2	37.3	24.1	238.0	232.4
Standard deviation	9.0	9.5	8.3	5.7	11.9	10.5
% positive	90.0	79.0	100.0	95.0	100.0	100.0

Note: The table shows, for each period and pair of markets, some summary statistics of the 100 averages of estimations of the relative mean distances between the sets of discount factors in sub-markets *A* and *B*. For the pair US-DE the relative distance is calculated as the difference between averages of mean distances when sub-markets A and *B* are made up of stocks belonging, respectively, to the US and German markets and averages of mean distances when both sub-markets are made up of stocks belonging to the US market. Each average is computed with a fixed sub-market *A*, made up of 10 American stocks, and 100 different sets D_B. Sub-market *B* is a sample of 10 stocks quoted in one of the three markets studied. For the pair US-FIX the relative mean difference is calculated as the difference between the mean distance between sub-market *A* and the fixed set and the average of the mean distances when both sub-markets are made up of stocks belonging to the US market.

Chart 5. Distribution of the relative mean distances (in basis points) between sets of stochastic discount factors, with the United States as the benchmark

1990–94

1995–99



US-DE US-ES US-FIX

Note: See the note to Table 8 for an explanation.

Table 9
Mean distances (in basis points) between sets of stochastic discount factors, with Spain as the benchmark

	1990–94				1995–99			
	ES-ES	ES-DE	ES-US	ES-FIX	ES-ES	ES-DE	ES-US	ES-FIX
Mean	449.9	460.6	467.3	655.2	434.0	439.1	441.4	639.3
Minimum	422.5	420.8	425.4	621.3	399.2	407.3	411.6	615.9
Maximum	502.2	518.6	529.6	698.7	476.1	476.8	478.2	677.1
Standard deviation	14.5	19.5	20.3	16.3	16.3	16.3	14.3	12.4
Average no. of iterations	2,434.5	2,463.7	2,463.0	2,747.3	2,393.8	2404.4	2,397.2	2,698.4

Note: The table shows, for each period and pair of markets, some summary statistics of 100 averages of the estimations of the mean distances between the sets of discount factors in sub-markets *A* and *B*. Averages of mean distances are computed for a fixed set D_A and 100 different sets D_B. D_A and D_B are, respectively, the sets of admissible discount factors in sub-markets A and B, and are defined as the discount factors that price stocks belonging to sub-markets *A* and *B*. Sub-market *A* is a sample of 10 stocks quoted in the benchmark market and sub-market. *B* is a sample of 10 stocks quoted in the other market of the pair. In the pair SPA-FIX, D_B is the set formed by all vectors whose components range between 0.5 and 1.5. This distance is used as a yardstick.

Finally, as a sort of robustness check, a parallel exercise is performed taking the Spanish market as the benchmark.[28] Also, as a by-product of this exercise we obtain estimations of the degree of integration between the German and Spanish markets. The number of assets in sub-markets *A* and *B* is again 10. The main results of this analysis appear in Tables 9 and 10 and Chart 6, which are, respectively, equivalent to Tables 7 and 8 and Chart 5. The results of this exercise are very similar to those obtained when the US market was the benchmark. In other words, the degree of integration between the Spanish market and the other two markets seems to increase during the second half of the decade. Interestingly, it is found that the integration between the German and Spanish markets is, in both periods, higher than that between the Spanish and US markets.

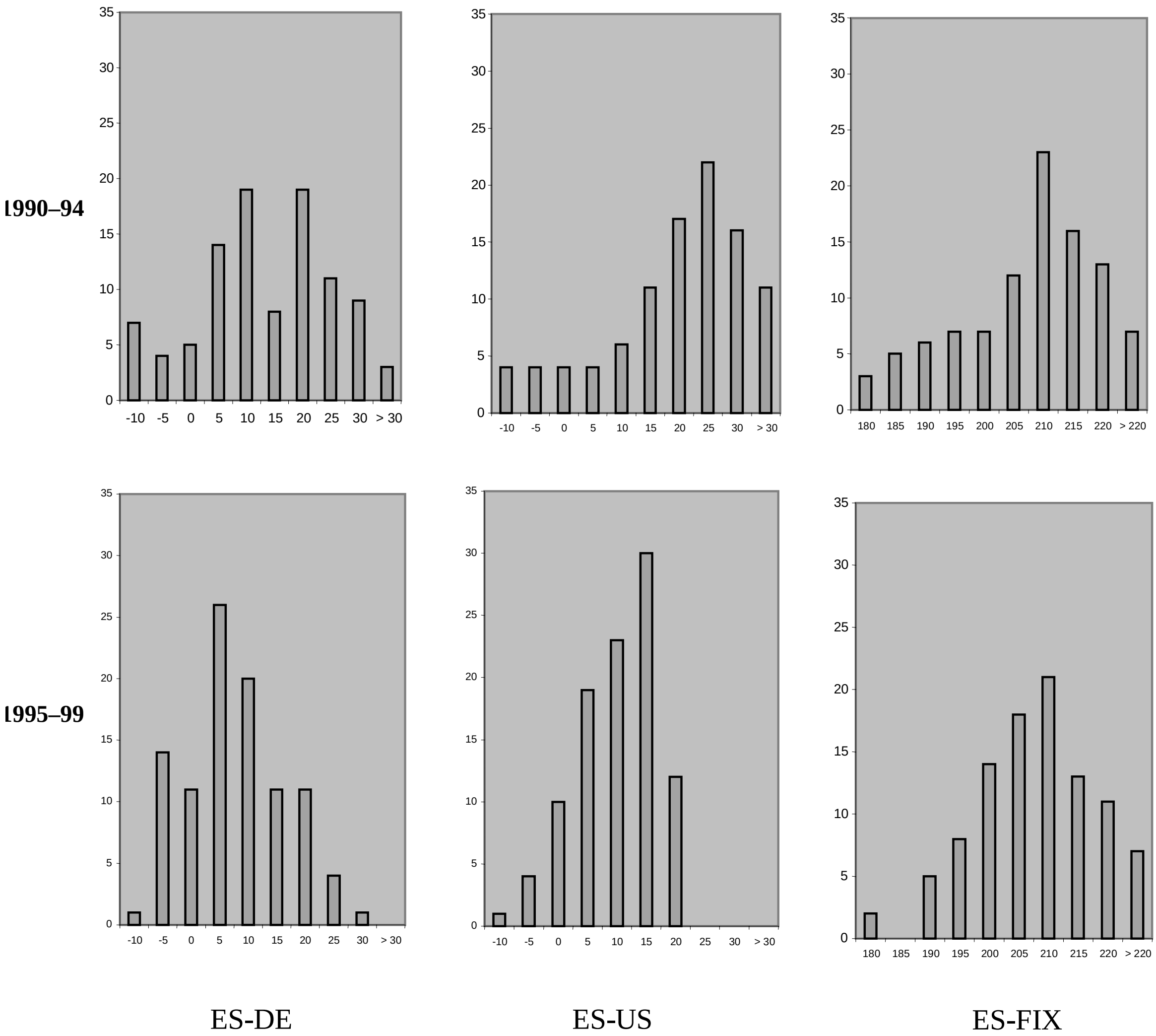
Table 10
Relative mean distances (in basis points) between sets of stochastic discount factors, with Spain as the benchmark

	ES-DE		ES-US		ES-FIX	
	1990–94	1995–99	1990–94	1995–99	1990–94	1995–99
Mean	10.7	5.0	17.4	7.4	205.4	205.2
Minimum	–24.0	–10.7	–24.9	–17.4	175.6	175.6
Maximum	38.4	25.2	49.5	19.5	232.9	234.7
Standard deviation	12.4	8.6	13.0	7.0	12.2	10.6
% positive	84.0	74.0	88.0	85.0	100.0	100.0

Note: The table shows, for each period and pair of markets, summary statistics of the 100 averages of estimations of the relative mean distances between the sets of discount factors in sub-markets *A* and *B*. For the pair ES-DE the relative distance is calculated as the difference between averages of mean distances when sub-markets A and *B* are made up of stocks belonging, respectively, to the Spanish and German markets and averages of mean distances when both sub-markets are made up of stocks belonging to the Spanish market. Each average is computed with a fixed sub-market *A*, made up of 10 Spanish stocks, and 100 different sets D_B. Sub-market *B* is a sample of 10 stocks quoted in one of the three markets studied. For the pair ES-FIX the relative mean difference is calculated as the difference between the mean distance between sub-market *A* and the fixed set and the average of the mean distances when both sub-markets are made up of stocks belonging to the Spanish market.

[28] Due to the small number of assets available in the data set of the German market – 19 assets – we cannot take it as a benchmark.

Chart 6. Distribution of the relative mean distances (in basis points) between sets of stochastic discount factors, with Spain as the benchmark



Note: See the note to Table 10 for an explanation.

To sum up, the results of this section suggest that financial market integration between the domestic equity markets considered has increased during the 1990s. This result seems to be robust as it holds for all the three pairs of markets and for both of the measures of financial integration estimated.

4. Conclusions and policy implications

During the 1990s, the linkages between national stock exchanges seem to have increased. Not only has the weight of foreign assets in agents' portfolios increased but so also have the correlation between stock indices and the ability of each market return to explain the behaviour of returns on other markets. Nevertheless, it is worth noting that these indicators cannot provide any information on the main driving forces behind these increasing linkages. In particular, as we have stressed in the paper, they cannot be used to assess whether there has been a genuine increase in the degree of integration between national financial markets. This is an important shortcoming given that the welfare and policy implications of the apparent higher linkages differ according to whether they are the consequence of greater market integration – i.e. fewer barriers of all kinds to free financial trade – or the consequence of, for example, a greater information globalisation in a world where barriers still remain.

Accordingly, we propose two refinements of a direct measure of financial market integration originally proposed by Chen and Knez (1995) and compute them for the US, German and Spanish stock exchanges in the 1990s. Our analysis shows that during the 1990s there has been an increase in the degree of integration among the markets considered.

This result has important implications when assessing the closer relationships observed between stock exchanges. Thus, for example, due to the entailed elimination of obstacles to free trade, greater financial market integration means higher financial market efficiency and an improvement in the risk-and-return combinations available to investors. This has to be viewed as a counterargument to those who believe that markets are now too vulnerable to news due to their excessive links.

Greater market integration, on the other hand, reduces the ability of domestically focused policies to deal with the new problems arising in financial markets. It might be argued that the closer we are to a single world market, the greater the need for worldwide supervision, particularly if this greater integration is the result of solid structural trends, as seems to be the case. Whether such worldwide supervision should be provided by a single supervisor or by a very closely linked group of supervisors is, however, a different question.

Annex

In Section 2, we use overall indices for seven stock exchanges and sector indices for the US stock exchange. The overall indices are the following:

S&P 500 for New York.[29]
FTSE All-Share for London.
CAC 40 for Paris.
IGBM for Madrid.
DAX 30 for Frankfurt.
MIB all shares for Milan.
Nikkei 225 for Tokyo.

In all these indices, stocks are weighted by their capitalisation and are calculated on a price-return basis – i.e. they only reflect capital gains. The source is the BIS, with the exception of the IGBM, where the source is the Bank of Spain.

The sector indices for the US exchange are seven of the sector indices of the S&P 500. They are the following:

XF: financial sector.
TECS: technology sector.
HLTS: healthcare sector.
CPGS: capital goods sector.
ENRS: energy sector.
XU: utility sector.
XT: transportation sector.

This data set is taken from Bloomberg.

In Section 3, we use information on prices and payoffs for a sample of portfolios of assets in each of three different markets – New York, Frankfurt and Madrid. The payoffs are indices calculated on a total-return basis representing the performance of portfolios of assets, and prices are the same series but lagged one period. For the Frankfurt market we take the 19 CDAX sector indices. These indices are calculated by the Deutsche Börse with the gross dividends reinvested in the index and with correction for capital increases. For the NYSE we construct total-return indices for 80 of the industry indices of the S&P 500. The computation is performed reinvesting gross dividends into those industry indices. More formally, we use the following expression:

$$TRI_t = \prod_{i=0}^{t} (1 + \frac{d_i}{I_i}) I_t$$

where TRI_t stands for total return index in period t, d_i is the sum of all gross dividends – expressed in index points – paid in period i by stocks belonging to the index, and I_j for $j = i,t$ is the price index in period j. The information needed to construct the previous data set was taken from Bloomberg.

Finally, for the Madrid exchange, we construct 43 indices representing the total return on 43 of the stocks which have been listed throughout the period studied. The total return is computed applying the previous expression, when the price index has been corrected for capital increases. The latter index is calculated after eliminating the impact of the correction for dividends made by the Bolsa de Madrid[30] in its individual price indices. The source of the data we use to compute these indices is the Bank of Spain for individual indices and the Bolsa de Madrid for dividends.

---

[29] In fact, the S&P 500 index also includes stocks quoted on other exchanges such NASDAQ and AMEX. However, the number of assets quoted on the NYSE represents more than 90% of the total.

[30] The Bolsa de Madrid calculates individual price indices for those stocks belonging to the global index IGBM. These indices are corrected for dividends in such a way that the drop in price on the ex-dividend day is eliminated, but as they are not reinvested into the index this correction was not useful for our purpose. That is why we have eliminated the impact of this correction.

Bibliography

Adler, M and B Dumas (1983): “International Portfolio Choice and Corporation Finance: A Synthesis”. *Journal of Finance*, 38, pp. 925-84.

Black, F (1976): “Studies in stock price volatility changes”. *Proceedings of the 1976 Business Meeting of the Business and Economics Statistics Section, American Statistical Association*, pp. 177-81.

Bollerslev, T (1986): “Generalised autoregressive conditional heteroskedasticity”. *Journal of Econometrics*, 31, pp. 307-27.

Chen, Z and P J Knez (1995): “Measurement of Market Integration and Arbitrage”. *Review of Financial Studies*, 8 (2), pp. 287-325.

Engle, R F , T Ito and W L Lin (1988): “Meteor showers or heat waves?: intra-daily volatility in the foreign exchange market”. NBER Working Paper.

Engle, R F and V K Ng (1993): “Measuring and Testing the Impact of News on Volatility”. *Journal of Finance*, 5, 1749-78.

Glosten, L, R Jagannathan and D Runkle (1989): “Relationship between the expected value and the volatility of the nominal excess return on stocks”. *Working Paper*, Department of Finance, Columbia University.

Hansen, L P and R Jagannathan (1991): “Implications of Security Market Data for Models of Dynamic Economies”. *Journal of Political Economy*, 99, pp. 225-62.

Hansen, L P and R Jagannathan (1997): “Assessing Specification Errors in Stochastic Discount Factor Models”. *The Journal of Finance*, 52 (2), pp. 557-90.

Le, S V (1991): “International investment diversification before and after the October 19, 1987 stock market crisis”. *Journal of Business Research*, 22, pp. 305-10.

Taylor, M P and I Tonks (1989): “The Internationalisation of Stock Markets and the Abolition of UK Exchange Control”. *Review of Economics and Statistics*, 71, pp. 332-6.

Decomposing the relationship between international bond markets

Andrew Clare and Ilias Lekkos[1]

1. Introduction

The correlations between major asset classes are of concern and interest to monetary authorities and financial regulators alike – the potential for a worldwide decline in consumption which might result from a dramatic fall in equity market wealth could have serious implications for both the health of financial institutions and that of the real economy. This concern is reflected in the academic literature, where an increasing number of researchers have tried to understand the characteristics of these linkages and the nature of the processes by which information flows between markets. Perhaps the main catalyst for this concern in recent years was the equity market crash of October 1987. This event more than any other highlighted the high levels of correlation between national equity markets at times of extreme market stress.

However, of equal importance is the relationship between international bond markets. Typically, monetary authorities are able to influence directly only the very short end of the term structure. Nevertheless, given that the long bond rate is determined by expectations about future short-term real interest rates and inflation, a credible monetary policy should trigger a transmission mechanism through which monetary policy actions are passed through to the whole of the term structure. As the covariation between government bond rates in different countries increases, the ability of monetary authorities to influence the term structure may decline, and hence their ability to control domestic inflation may also decline.

Correlation between bond markets may arise through a number of channels, for example: if there is a world price of risk; if real rates are determined by global factors; or if there is a "flight to quality" in times of financial stress. Unconditional measures of the correlations between major international bond markets showed that the linkages between these markets increased from the 1960s until the early 1980s, but, according to Solnik et al. (1996) and Christiansen and Pigott (1997), these correlations have not exhibited a clear trend since this time. However, while simple unconditional, rolling measures of international bond market correlations may not have been trending up in recent times, the question of how much control monetary authorities can bring to bear upon the shape of the yield curve through changes in short rates still remains. Another issue relates to the extent (in terms of duration and magnitude) to which the slope of the yield curve is influenced by international factors during periods of financial crisis. Finally, another important and related issue is the extent to which comovements in long bond rates, or indeed the components of these comovements, change during periods of financial market stress. This paper addresses all of these issues.

Using the intuition from the rational expectations hypothesis of the term structure (REHTS), we decompose the long bond rates of Germany, the United Kingdom and the United States into their respective "fundamental" and risk premium components.[2] The decomposition is achieved by using the

---

[1] We would like to thank Roger Clews, Nicola Anderson, James Proudman, Nikolaos Panigirtzoglou and participants at the BIS Autumn 1999 Meeting of Central Bank Economists for comments on an earlier draft of this paper. We would like to point out that the views expressed in this paper are those of the authors and do not necessarily represent those of the Bank of England. E-mails: andrew.clare@bankofengland.co.uk and ilias.lekkos@bankofengland.co.uk

[2] Our technique does not allow us to distinguish between more permanent risk premium components and temporary contagion effects. However, for expositional simplicity we use the term risk premium in this paper to mean some combination of the two.

Campbell and Shiller (1987) VAR methodology. Each VAR which we estimate contains both domestic and foreign conditioning variables, which means that we can separate that portion of the variance of the slope of the yield curve which is influenced by domestic factors from that portion which is driven by international factors. We then turn our attention to calculating a conditional measure of international bond market covariation, decomposing this measure into its fundamental and risk premia components, by invoking the REHTS. We extend our analysis to consider the relationships between sterling and US dollar swap markets, a relationship which to our knowledge has not been considered in this context by previous researchers. Finally, because we estimate each of the VARs on a rolling basis, we can monitor the time variation in both the variance and the covariance decompositions.

Our results suggest that there have been periods associated with financial market crises when the slopes of the government yield curves studied here are determined more by international than by domestic factors, for example during the sterling exchange rate crisis of 1992. However, our evidence suggests in general that once the crisis has passed, the yield curves become dominated by domestic factors once again. With respect to the covariance between bond yields, we find that while the total covariance between the markets is fairly stable over time, the components of this covariance can vary considerably over time. The rest of the paper is organised as follows: in Section 2 we briefly outline relevant academic literature on the topic of financial market linkages; in Section 3 we describe our methodology; in Section 4 we present the data used here; in Section 5 we present our results; and finally, Section 6 concludes the paper.

2. Brief literature review

One of the main spurs to research into financial market linkages was the October 1987 stock market crash. Koutmos and Booth (1995) (amongst others) find evidence to suggest that interdependencies between the world's three major stock markets – London, New York and Tokyo – increased after the 1987 crash. This apparent increase in the linkages between national equity markets could be due to the globalisation of finance, and hence to an increase in the presence of "international investors". Alternatively, volatility transmission could be the result of contagion, as proposed by King and Wadhwani (1990), where, for example, agents do not assess the economic implications of news from an overseas market for their own and simply respond by "shooting first and asking questions later" (see Shiller et al. (1991)).

While some early studies of the informational linkages between markets investigated the interdependencies between conditional first moments (see, for example, Eun and Shim (1989), King and Wadhwani (1990) or Koch and Koch (1991)), more recent studies have focused upon the relationships between conditional first and second moments. Engle et al. (1990) examine the phenomenon of volatility clustering in foreign exchange markets, making the distinction between what they term to be "heat wave" and "meteor shower" effects: the former referring to volatility which is not transmitted to other markets, the latter referring to volatility which is transferred between markets. The Engle et al. study finds more evidence for meteor shower than for heat wave behaviour in the foreign exchange data in their study. Using daily data on London, New York and Tokyo stock indices, Koutmos and Booth (1995) estimate a multivariate E-GARCH model to test for spillover effects between the conditional first and second moments of returns in these markets. While they find clear evidence of such spillovers, they also find that the volatility transmission is asymmetric, with negative shocks from one market having a larger impact upon the volatility of another market than equivalent positive shocks. Following King and Wadhwani (1990), other studies have couched the volatility transmission issue as a signal extraction problem, where agents in the local market have to extract from any news event that portion of the news which is relevant to their market. For example, Lin et al. (1994) decompose return surprises from one market into its global and local components using Kalman filtering techniques.

An alternative approach to the analysis of the relationship between national equity markets can be found in Ammer and Mei (1996), who use a variant of the Campbell and Shiller (1987) variance decomposition for equities to analyse the relationship between US and UK stock returns. From 1957 to 1989 they find that there was an increase in the correlation both between expected dividends and between risk premiums in these two countries, but that these correlations have changed little since 1989.

Finally, some researchers have also considered the relationship between bond and stock markets. Shiller and Beltratti (1992) and Campbell and Ammer (1993) investigate the relationship between bond and stock markets using the VAR approach of Campbell and Shiller (1987) to decompose asset returns. Shiller and Beltratti find that the negative relationship observed between real stock prices and long-term interest rates is much bigger in magnitude compared to the relationship implied by the simple rational expectations present value model. Using a similar VAR decomposition for US data, Campbell and Ammer (1993) find that stock returns are driven mainly by news about future stock returns, while bond returns are predominantly driven by inflation, thus explaining the low correlation between the returns on these two long-term assets.

To our knowledge, far fewer researchers have investigated the relationships between international bond markets (for an exception to this general rule, see Dahlquist et al. (1999)). The purpose of this paper, then, is to add to the literature on financial market linkages by considering the links between fixed income markets.

3. Methodology

3.1 Structural decomposition of bond market covariation

We begin by outlining a decomposition of the covariation between long-term bond rates. To achieve this more structural approach to the linkages between international bond markets, we make use of the REHTS. In its original form the REHTS defines current long-term interest rates as an average of expected future short-term rates plus a constant risk premium. Given the overwhelming empirical evidence against the pure expectations hypothesis, we adopt a more general version of the REHTS that allows for a time-varying, risk premium (see Evans and Lewis (1994)). For pure discount bonds we can write:

$$(1) \qquad R_{k,t} = R^e_{k,t} + RP_{k,t}$$

where $R_{k,t}$ is the yield on a k-maturity pure discount bond and $RP_{k,t}$ is the risk premium at time t associated with buying a long bond relative to rolling over one-period bonds. $R^e_{k,t}$ is the theoretical k-maturity rate according to the expectations hypothesis given by:

$$(2) \qquad R^e_{k,t} = \frac{1}{k}\sum_{i=0}^{k-1} E_t r_{1,t+i}$$

where E_t denotes the market's expectations conditional upon information available at time t and $r_{1,t+i}$ is the one-period rate at time $t+i$.

Similarly we can define foreign bond rates as:

$$(3) \qquad R^*_{k,t} = R^{e*}_{k,t} + RP^*_{k,t}$$

Given equations (1) and (3), the covariance between domestic and foreign interest rates can be written as:

$$(4) \qquad \begin{aligned} Cov(R,R^*) &= Cov(R^e + RP, R^{e*} + RP^*) \\ &= Cov(R^e,R^{e*}) + Cov(R^e,RP^*) + Cov(RP,R^{e*}) + Cov(RP,RP^*) \end{aligned}$$

How can we interpret these components? The first component in expression (4) measures that part of the covariation between two bond markets which can be attributed to the covariation in investors' expectations about future short-term interest rates in the two countries. Given that these expectations will reflect considerations about the future path of inflation, real interest rates and the monetary policy stance in each country, we assume that this component reflects the part of the total covariation due to "economic fundamentals" between the two economies. If the two economies track each other through the business cycle, we might expect the links between the two bond markets to be quite strong. The remaining components are a direct result of our use of the REHTS. In the absence of a bond market risk premium the fully anticipated rational expectation of the long rate will equal the actual long rate. We can therefore interpret the difference between R_k and R_k^e as the risk premium required for holding government bonds, *RP*. The second (third) component then represents the covariation between domestic (foreign) fundamentals and the foreign (domestic) interest rate risk premium. Finally, the fourth component measures the covariation between domestic and foreign risk premia.

3.2 Generating expectations of future long rates

One difficulty in calculating the covariance decomposition given by expression (4) is that none of the long-term interest rate components are directly observable. Since the components of expression (4) depend upon long-horizon expectations of short-term interest rates, we need some way to condition these expectations. To this end we use the vector autoregression (VAR) methodology to calculate multiperiod expectations of the long rate (see Campbell and Shiller (1987)).[3]

Having chosen this VAR methodology, the next issue relates to the choice of conditioning variables. Campbell and Shiller (1987) use a two-dimensional vector of state variables, which includes the changes in the short rate and the slope of the term structure, in undertaking this exercise using US data. An assumption inherent in such a formulation is that investors' expectations about future short-term rates are affected only by information concerning domestic fundamentals as reflected in the short rate and the slope of the term structure. However, since the aim of this paper is to investigate the linkages between national bond markets, we condition expectations about future long rates on both domestic and international measures of the short rate and the slope of the term structure. Our intention then is to formulate a VAR using information from the bond markets of Germany, the United Kingdom and the United States in such a way that interest rate expectations are jointly determined, thus allowing for possible interactions between domestic and international fundamentals. In order to achieve this interaction, we expand the information set to include information on three different term structures.[4] As a result the vector of state variables is defined as:

$$(5) \qquad z_t = [\Delta r_{1year,t}, \Delta r^*{}_{1year,t}, \Delta r^{**}_{1year,t}, Slope_t, Slope_t^*, Slope_t^{**}]'$$

where the superscripts * and ** relate to the first and second "foreign" markets respectively.

Having chosen the information set, we can follow Campbell and Shiller (1987) and define the theoretical slope of the term structure under the expectations hypothesis, $s_{k,t}^e$, as:

$$(6) \qquad s_{k,t}^e = R_{k,t}^e - r_{1,t}$$

Substituting (2) into (5), we get:

$$(7) \qquad s_{k,t}^e = \frac{1}{k}\sum_{i=1}^{k-1}(k-i)E_t(\Delta r_{1,t+i+1})$$

where Δ denotes the one-period backward difference operator defined as $\Delta r_{1,t+i+1} = r_{1,t+i+1} - r_{1,t+i}$.

---

3 For a more detailed discussion on alternative methodologies used to evaluate multiperiod expectations of unobserved variables and their shortcomings relative to the VAR approach, see Campbell and Ammer (1993).

4 The number of countries included in the vector of state variables is limited only by data availability.

Similar expressions to (6) and (7) hold for $s_{k,t}^{e*}$ and $s_{k,t}^{e**}$.

To estimate the expectations of future short-rate changes, we assume that the vector of state variables defined by (5) follows a first-order VAR process:

$$(8) \qquad z_t = \mathbf{A} z_{t-1} + w_t$$

where z_t is the vector of state variables given by (5), **A** is the matrix of the VAR coefficients and w_t is the vector of residuals. By including the interest rate changes rather than the levels, we ensure stationarity in the VAR. Furthermore, for reasons of notational simplicity and computational convenience, we demean the variables before including them in the VAR. Finally, we note that the assumption of the first-order VAR process is not restrictive.[5]

Based on this formulation, the long-horizon expectations of changes in one-period interest rates *j*-periods in the future, *j*=1,...,*k*-1, can be estimated by:

$$(9) \qquad E_t(\Delta r_{1,t+j}) = \mathbf{h_1^T A}^j \mathbf{z_t}$$

$$(10) \qquad E_t(\Delta r_{1,t+j}^{*}) = \mathbf{h_2^T A}^j \mathbf{z_t} \quad \text{and}$$

$$(11) \qquad E_t(\Delta r_{1,t+j}^{**}) = \mathbf{h_3^T A}^j \mathbf{z_t}$$

where $\mathbf{h_1^T} = [1,0,0,0,...]$, $\mathbf{h_2^T} = [0,1,0,0,...]$ and $\mathbf{h_3^T} = [0,0,1,0,...]$ are used to pick out the first, second and third element of the state vector.

Once the matrix **A** of VAR coefficients is estimated then for each *t*, *t*=1,...,*T*, the expectations of future changes in interest rates can be generated using expressions (9), (10) and (11), and the theoretical term structure slopes by using expression (7). We can calculate the theoretical long-term interest rate by solving (6) with respect to $R_{k,t}^{e}$. The differences between the theoretical and actual long-term rates provide an estimate of the domestic and foreign bond market risk premium, $RP_{k,t}$. Estimates of $R_{k,t}^{e*}$, $RP_{k,t}^{*}$ and $R_{k,t}^{e**}$, $RP_{k,t}^{**}$ are produced by a similar procedure.[6] Given the estimated theoretical long rates and the risk premia, then, for each pair of countries, components of the covariance between actual interest rates can be calculated according to expression (4).

Our intention is not only to identify the covariance components and the importance of domestic and international factors in determining interest rates, but also to examine how these derived variables vary over our sample period. To capture this effect, we adopt a rolling estimation procedure where the VAR described above is estimated using one year's worth of data. We then roll forward the estimation window by one week and repeat the procedure outlined above until the end of the sample period. By doing this, we can generate a time series of the components of expression (4).

Finally, the estimation of a VAR allows us to decompose the variance of the slopes of both the domestic and foreign term spreads, a procedure which is now common practice in papers using unrestricted VARs of the kind used here (see Sims (1980) for a description of the technique). The variance decomposition provides us with an estimate of the proportion of the movement in one variable which can be attributed to shocks in other variables in the VAR. Since we estimate the VARs on a rolling basis, we also create a time series of this variance decomposition allowing us, for example, to gauge the time-varying impact of shocks to overseas interest rates on the slope of the UK yield curve.

---

5 Campbell and Shiller (1988) demonstrate that it is straightforward to modify the model to allow for a higher VAR order.

6 These estimates of the risk premia will be accurate provided that we include in our model all the relevant information that investors use to form their expectations about future interest rates and that the dynamics of the VAR are correctly specified. If these conditions are not met, estimates of risk premia will be biased upwards.

3.3 Extending the analysis to interest rate swaps

Interest rate swaps are contracts which allow two counterparties to exchange fixed for floating interest rate payments. The fixed rate of the swap is usually defined as the rate of the underlying government bond plus a mark-up, known as the spread. This spread is often used to make inferences about default risk in an economy, e.g. the sterling (US dollar) swap spread is often used in the financial press as a measure of default risk in the United Kingdom (United States). It is possible to extend the VAR methodology to investigate the importance of domestic versus foreign factors in determining the size of the swap spread, enabling us, for example, to trace the time path of the apparent credit crunch which affected interest rate swap markets after the recent Russian debt crisis. The main aim of this analysis is to identify periods where conditions in international swap markets override domestic factors as the driving force of swap spreads. During these periods the interpretation of the spread as an indicator of aggregate domestic default risk[7] may be misleading.

Previous research (see, for example, Sun et al. (1993) or Minton (1997)) has shown that long-term swap spreads are affected by changes in the slope of the term structure. Hence, we can define the following vector of state variables:

(12) $$z_t = [\Delta r_{1year,t}, \Delta r^*_{1year,t}, Slope_t, Slope^*_t, swap\ spread_t, swap\ spread^*_t]'$$

The analysis of swap spreads has been limited to only two countries purely due to data availability, as discussed in the following section. Using the vector of state variables given in expression (12), we can again calculate the rolling variance decomposition, as outlined in Section 3.2.

4. Data

4.1 Data description

We estimate the VARs using weekly one- and 10-year US, UK and German interest rates. These are zero coupon interest rates estimated from the prices of coupon-paying government bonds using the

Table 1
Descriptive statistics

Rates	From	To	No. obs.	Mean	St. dev.	Min.	Max.
US interest rates							
1-year	15 August 1990	8 August 1999	456	5.23	1.07	3.13	7.99
10-year	15 August 1990	8 August 1999	456	6.64	0.94	4.55	8.90
Slope	15 August 1990	8 August 1999	456	1.42	1.01	0.04	3.63
UK interest rates							
1-year	15 August 1990	8 August 1999	456	7.06	1.93	4.71	13.37
10-year	15 August 1990	8 August 1999	456	7.71	1.62	4.16	11.62
Slope	15 August 1990	8 August 1999	456	0.66	1.30	–1.87	3.10
German interest rates							
1-year	9 October 1991	8 August 1999	408	5.01	1.91	2.55	10.68
10-year	9 October 1991	8 August 1999	408	6.33	1.15	3.77	8.53
Slope	9 October 1991	8 August 1999	408	1.33	1.36	–1.87	3.54
UK swap spreads							
10-year	15 August 1990	8 August 1999	456	0.38	0.20	0.00	1.05
US swap spreads							
10-year	15 August 1990	8 August 1999	456	0.36	0.16	0.10	0.89

[7] See, for example, "Swap spreads show a new aversion to risk", *Financial Times*, 10 August 1999, p. 24.

Svensson methodology (Svensson (1994, 1995)).[8] The zero coupon data available for the three countries begin on different dates: from January 1979 for the United Kingdom, from August 1990 for the United States and from October 1991 for Germany.[9] Given that the VARs are jointly estimated for three countries at a time, the estimation period for each VAR is set equal to the period over which overlapping data between the three countries are available. Descriptive statistics for the data used are given in Table 1.

In addition, we extend our analysis to interest rate swap spreads. Only sterling and US dollar swap rates were available to us for a sufficient span of time. The swap data span the period from August 1990 to August 1999. From zero coupon swap rates[10] we subtract the equivalent maturity zero-coupon interest rate estimated from the appropriate Svensson yield curve to provide estimates of the sterling and dollar swap spreads.

5. Results

We now present the results relating to various versions of the VAR outlined in Section 4 above. This VAR is estimated using government bond market data for Germany, the United Kingdom and the United States. We also estimate the VAR given in expression (12) using swap market data. We begin by discussing the results of the variance decompositions of these VARs and then move on to discuss the decomposition of the covariance.

5.1 Variance decomposition results

5.1.1 Government bond market results

In Figure 1 we present the variance decomposition for the slope of the US yield curve, based upon a VAR which includes German, UK and US variables. The figure reports the proportion of the variance of the slope of the term structure that can be attributed to shocks in the variables of the VAR, 26 weeks into the future.[11] One known shortcoming of the VAR methodology is that the variance decomposition results may be influenced by the ordering of the variables in the VAR. In our VAR the first variable in the state vector is the change in short-term US interest rates, followed by the change in German and then UK short-term rates, which are followed in turn by the slopes of the US, German and UK yield curves. The raison d'être for this ordering is that shocks to short-term rates should affect the slopes of the yield curves. The ordering of the countries, with the United States first then Germany and then the United Kingdom, reflects our priors of the importance of these economies and their respective bond markets in a global sense.

---

8 More details on the implementation of the Svensson methodology and the estimation of zero coupon term structures are provided in Appendix A.

9 From January 1999 the German rates are replaced by euro interest rates.

10 Appendix B gives more details about the estimation of zero coupon interest rates estimated from swap rates.

11 The variance decomposition results presented here could be based upon coefficients which are poorly determined. To test for this possibility, and to test for causation between foreign influences on the domestic term structure, we test a null hypothesis that the VAR coefficients relating to the foreign variables are jointly insignificant, i.e. that they do not help to predict the domestic slope and interest rate change. We undertake this test on a rolling basis. In the interests of brevity, we do not report the results in detail here; however, we find that for all of the VARs presented in this paper the null hypothesis of no foreign influence on domestic interest rates can be rejected for the majority of the sample period considered here, and in particular for the "crisis" periods. An alternative way of interpreting these results is that dual causality, in the Granger causality sense of the term, exists between these markets. These results are of course available on request from the authors.

Figure 1: Variance decomposition of US Slope

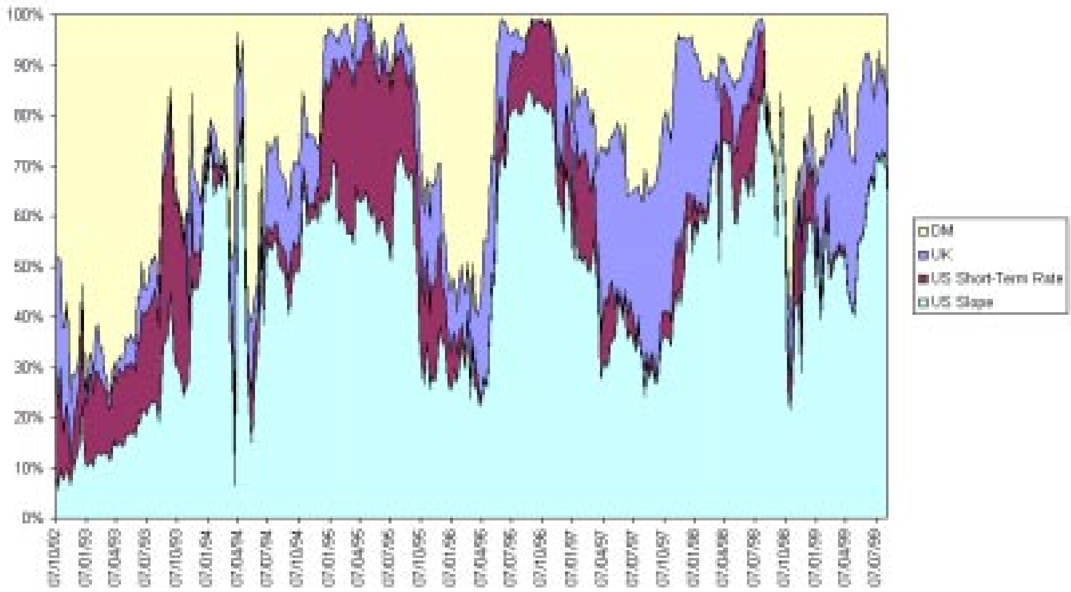


Figure 1 shows that on average 60% of the slope of the US yield curve is determined by US variables, and therefore that there is a significant international component in this slope on average, and during four periods in particular. The first period relates to the sterling exchange rate crisis when the United Kingdom was forced out of the ERM in 1992. During this period the German government bond market was exerting a considerable influence upon the US slope until “normal service” was resumed in early 1995. The second period of international influence relates to a period of monetary easing in Germany in preparation for the third stage of EMU in 1996. This easing was followed by a wave of associated monetary easings across other EU countries. This monetary easing was also associated with considerable EU convergence trades across international bond markets at this time. The third period appears to relate to the Asian crisis of 1997, while the fourth relates to the Russian debt crisis of 1998. These last two episodes were of course widely recognised as “international crises”, and therefore we believe that the UK and German markets are proxying here for wider international influences. Finally, and perhaps most importantly, we should note that after each of these four periods domestic factors gradually returned as the dominant influence over the slope of the US yield curve.

In Figure 2 we report the variance decomposition results for the slope of the German curve. On average, 70% of the slope of the German yield curve is determined by the German variables in the system. This is particularly true during the ERM crisis, where the variance in the German rates accounted for almost 100% of the variance in the yield curve. The results also indicate that the crisis in Asian financial markets in 1997 and the Russian debt crisis in 1998 both had a relatively large influence, via UK and US bond markets, upon the term structure of German government debt. Finally, we might also note that there has been an increase in the influence of US bond markets in the second half of our sample.

Figure 3 reports analogous results for the factors influencing the slope of the UK yield curve. The results show that the UK term structure is influenced the most by international factors, with just less than 40% of the slope on average being determined by the UK variables in the system. The German bond market exerts a large influence on the UK bond market in two periods. The first period coincides with the ERM crisis in 1992. The second, spanning 1995 and 1996, coincides with the loosening of German monetary policy during this period, as outlined above. Interestingly, there are also two periods where the US bond market influences the UK bond market. The first follows the ERM exchange rate crisis period in 1993 and 1994. The second period arguably begins before, but reaches a peak during the financial crisis in Asian markets and remains high until the impact of the Russian debt crisis declines towards the middle of 1999. Finally, Figure 3 also shows the brief but dramatic impact of the

Mexican crisis of 1994, revealing itself as a sharp increase in the proportion of the volatility of the UK yield slope which can be explained by US bond market variables.

Figure 2: Variance Decomposition of DM Slope

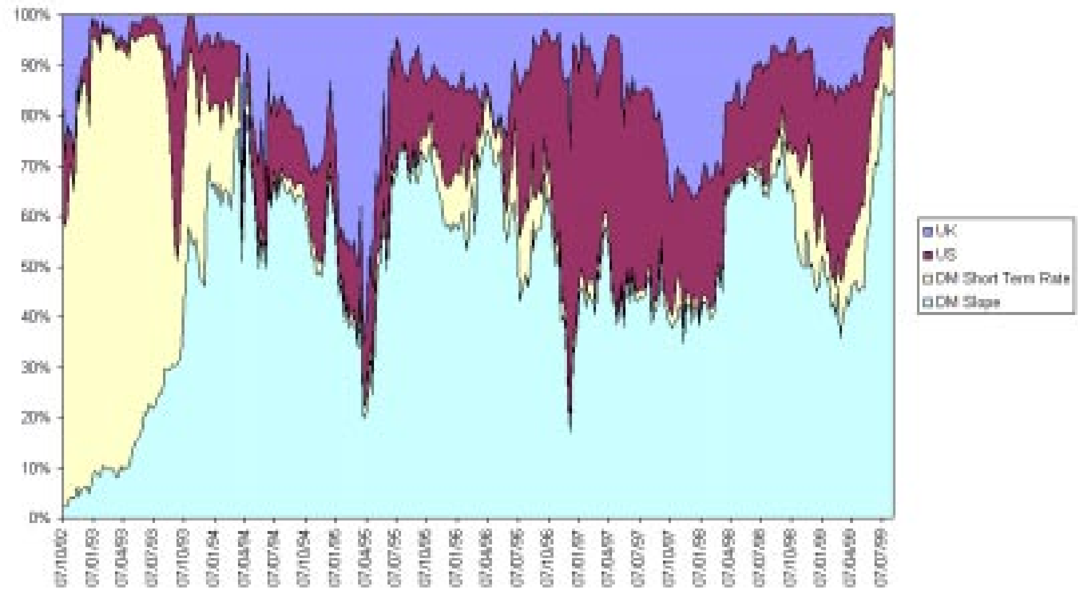
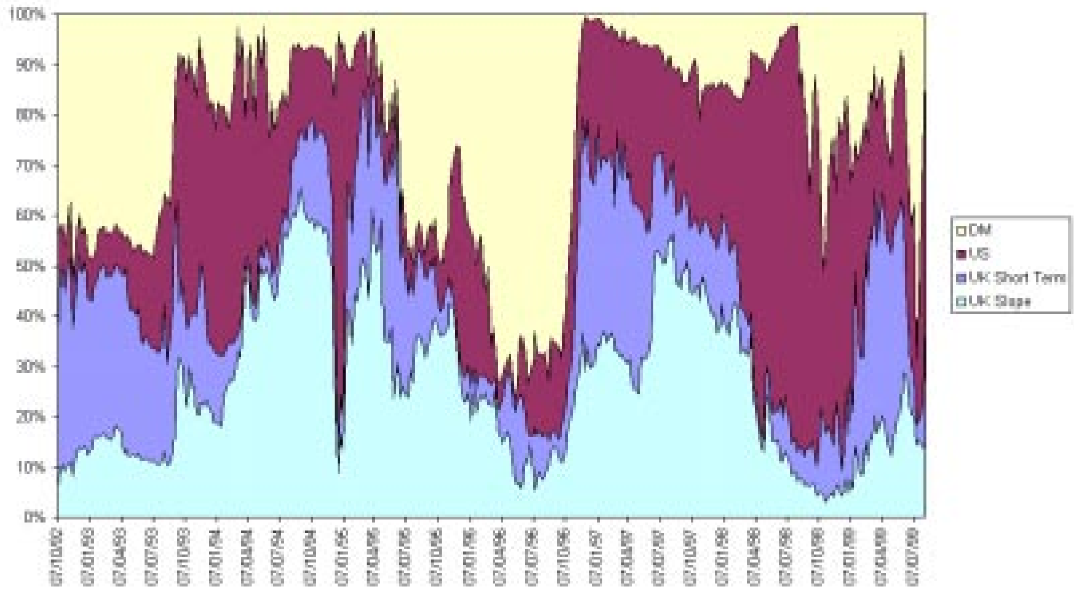


Figure 3 : Variance decomposition of UK Slope



We could summarise these results as follows: the variance of the slope of the UK yield curve appears to have been influenced most by international bond market factors, particularly the US market; while the variance of the slope of the US yield curve has tended to have been influenced by domestic factors, there have been significant periods of time when its variance has also been affected by international factors; finally, the variance of the slope of the German yield curve appears to have been the most domestically orientated of the three markets studied here, particularly during the early 1990s.[12]

[12] This result is robust to alternative VAR orderings.

5.1.2 Swap market results

Finally, we consider the variance decomposition of the relationship between the US dollar and sterling swap markets in Figures 4 and 5. The first variables in the VAR are the changes in short-term rates, followed by the term structure slopes and finally by the swap spreads. The US dollar variable always precedes its sterling counterpart. Figure 4 shows that the variance of the US dollar swap spread is virtually unaffected by the sterling spread, while the slope of the UK yield curve on average determines 15% of the variance of the US dollar spread. The main factor affecting the US dollar swap spread, other than own variation, is movements in the slope of the US term structure. This reflects the way practitioners price interest rate swaps relative to government bond yields with similar maturities. In contrast to this result, Figure 5 shows that the variance of the sterling swap spread is influenced by the slope of the US yield curve. Perhaps more importantly, it is heavily influenced by the US dollar swap spread towards the end of our sample, a period beginning with the Asian financial crisis and extending into the period surrounding the Russian debt crisis.

Figure 4: Variance Decomposition of the 10 Year US Swap Spread

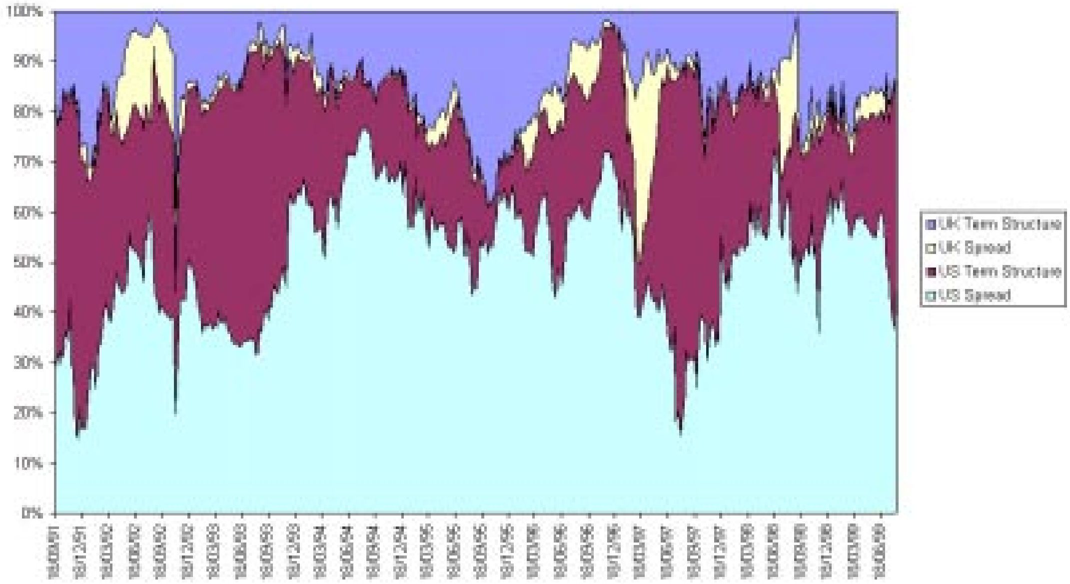
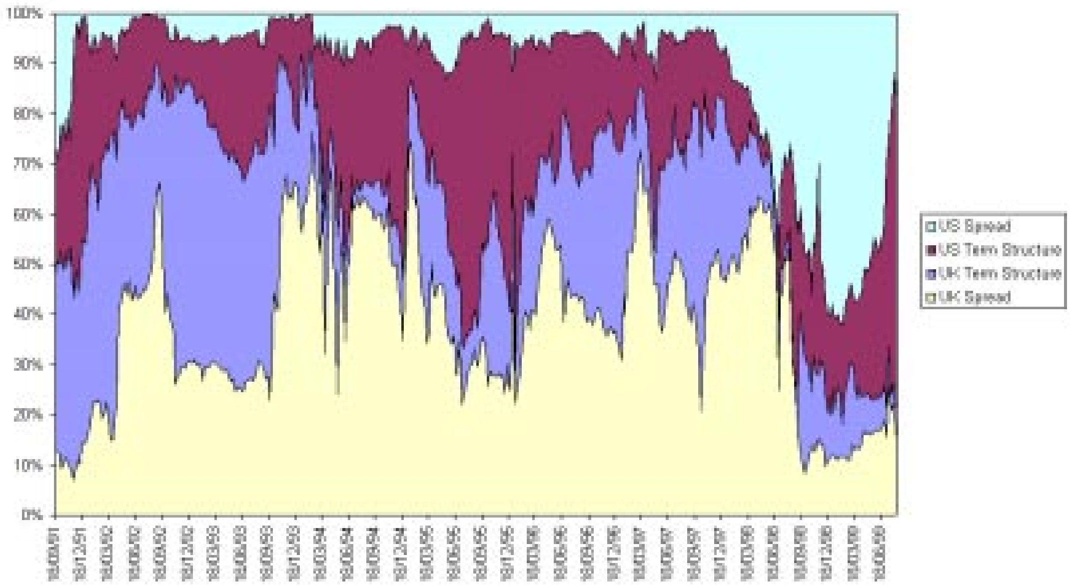


Figure 5: Variance Decomposition of the 10 Year UK Swap Spread

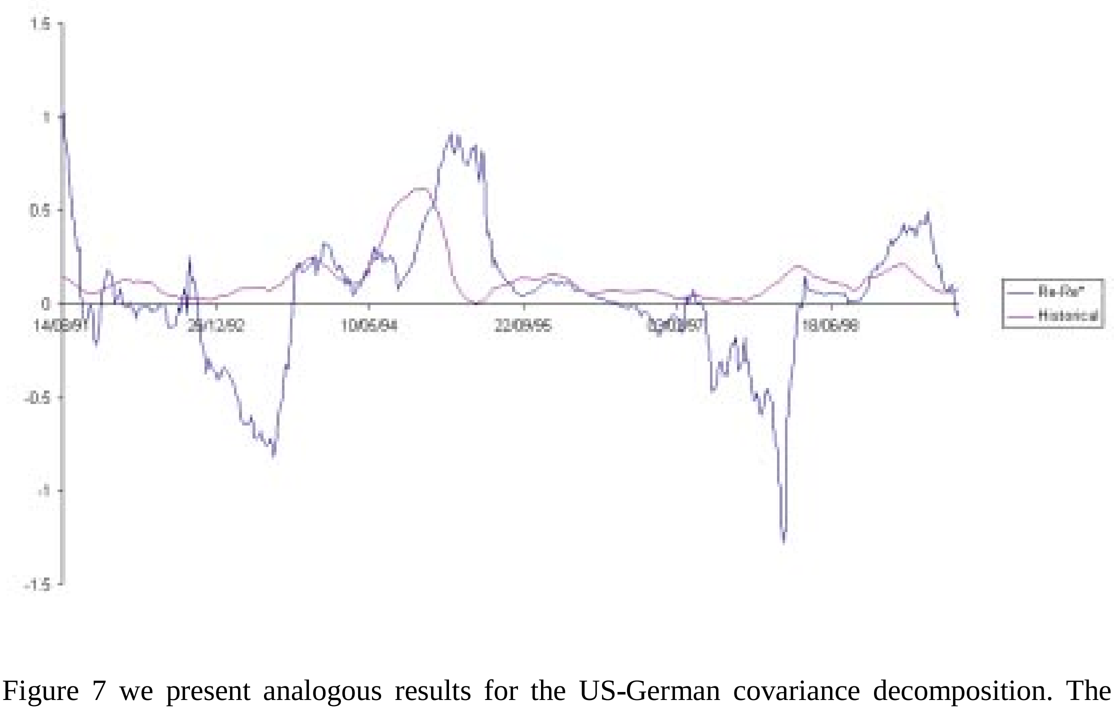


The results with respect to the sterling swap spread should act as a potential warning for those who believe that swap spreads are an indicator of domestic financial conditions. While this might be true for the US dollar swap market, clearly at the end of our sample the sterling swap spread was being more heavily influenced by developments in the US bond and US dollar swap markets than by UK factors.

5.2 Covariance decomposition results

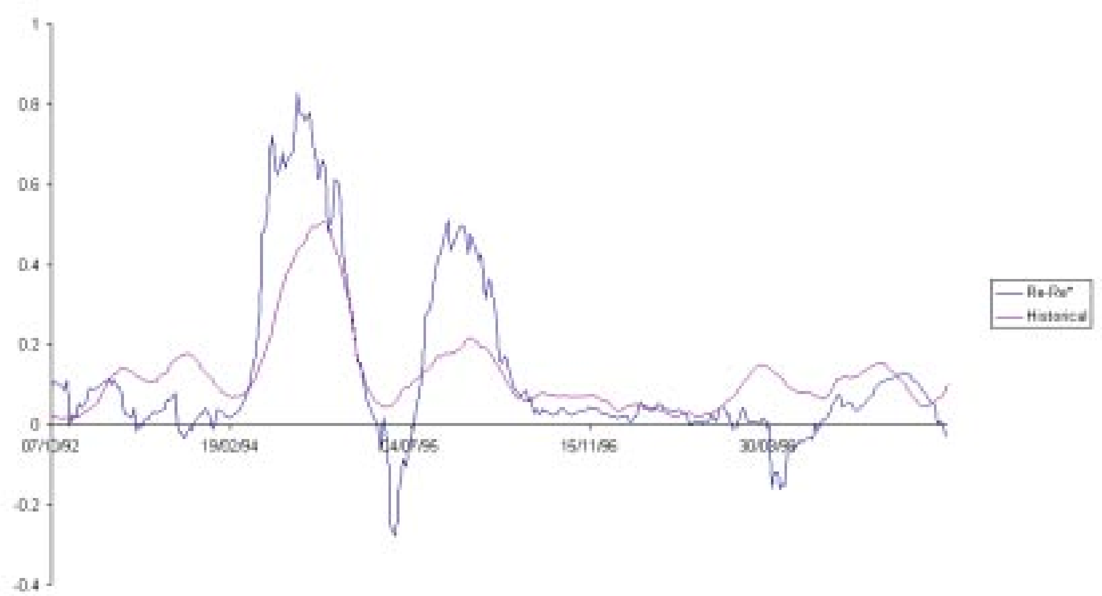
We now turn to the results of decomposing the covariances between the major government bond markets. In Figure 6 we present the unconditional covariance between UK and US long bond rates. In keeping with the results of Christiansen and Pigott (1997) and Solnik et al. (1996), we find no sign of an obvious increase in the total covariation between these two markets during the 1990s, which is always positive, although very close to zero for much of the period. Interestingly this covariance measure reaches a peak during 1994, not during the sterling, Asian or Russian crises. Figure 6 also shows the covariance over time between the REHTS-derived measures of expected long rates. The fact that this measure of covariance does not always track the total covariance closely indicates that at times the covariance between these markets is influenced very strongly by risk premium effects. This corroborates our previous findings that at times international factors exert considerable influence on the determination of the domestic interest rates, overriding in many cases considerations about domestic fundamentals. There are two such periods. Firstly, during the sterling exchange rate crisis in late 1992. The covariance between the REHTS-derived expectations of the two long rates indicates that the relationship should be strongly negative, reflecting the fact that the two economies were at different stages in the business cycle. However, since the total covariance is positive, this indicates that there were strong risk premium effects present at this time offsetting the influence of respective domestic economic conditions. The second notable deviation between the two series occurs during the Asian economic crisis, where domestic economic fundamentals were implying a negative covariance, but the impact of the crisis, which raised the total covariance between the two markets over this period, combined to produce a positive relationship. Finally, we might also note that there are also times when the REHTS-derived covariance term suggests a more positive relationship between the two markets than can be seen from the total covariance measure.

Figure 6 : Decomposition of Covariance between 10 year US-UK Interest Rates



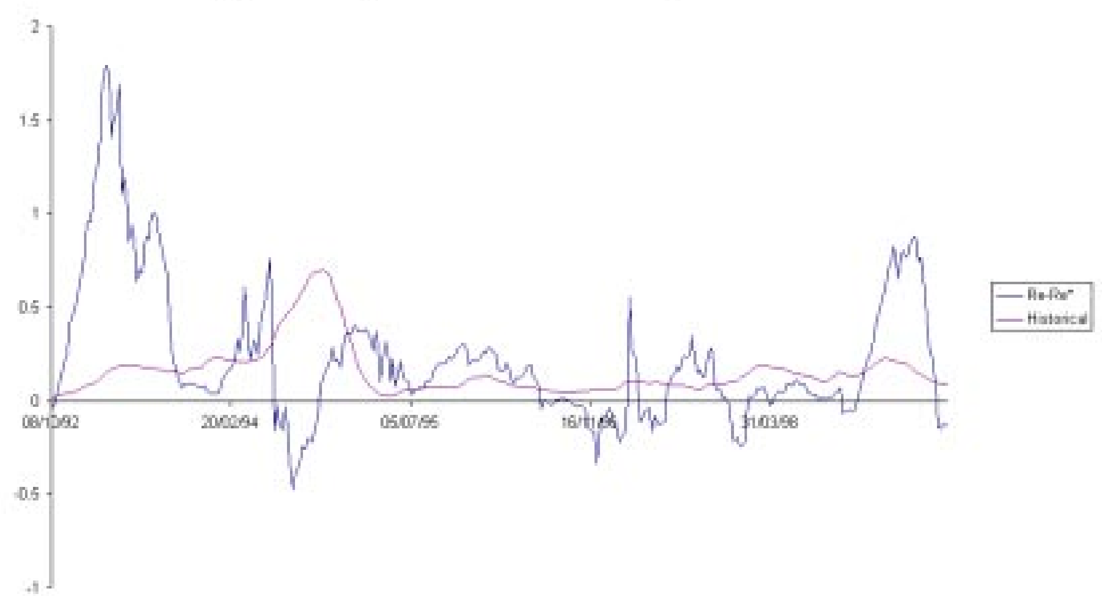
In Figure 7 we present analogous results for the US-German covariance decomposition. The total covariance between these two markets peaks in 1994. There is a noticeable, but small increase in this variable following the Asian crisis which persists until the end of our sample. Again this measure is always positive and close to zero for a significant portion of the sample. When we consider the difference between the total covariance and the REHTS-derived measure for the German-US pair, the results are in sharp contrast to those involving the United Kingdom and the United States. The REHTS-derived measure, with the exception of two minor, short-lived episodes in 1995 and in 1998, follows the total covariance measure fairly closely. Again this evidence is consistent with our previous findings. Variance decomposition results showed that, in contrast to the United Kingdom, the US and German yield slopes exhibit a smaller degree of variation due to international shocks. This result could be taken to indicate that the covariance between these two markets is driven more by macroeconomic fundamentals than by risk premia.

Figure 7 : Decomposition of Covariance between 10 year US-DM Interest Rates



The total covariance between the UK and German government bond markets, shown in Figure 8, reaches a peak in 1994 and remains, positive, but fairly low and stable during our sample period. The

Figure 8 : Decomposition of Covariance between 10 year DM-UK Interest Rates



sterling, Asian and Russian crises again seem to have had little impact upon total covariance over this period. There appear to be at least three periods where the REHTS-derived covariance component diverges substantially from the total measure. The first of these periods occurs after the United Kingdom's exit from the ERM in 1992, when the REHTS measure is strongly positive, while the total covariance measure remains positive, but small. This divergence suggests that the covariance between foreign risk premia and the REHTS measure of interest rate expectations is very negative over this period and analysis of this series confirms this to be true. During 1994, when the total covariance measure is at its maximum, the REHTS-derived measure is negative for a period, indicating strong positive correlations between risk premia. Finally, towards the end of our sample we see that the REHTS measure is indicating that the markets should be positively correlated while the total measure remains low, once again indicating that the risk-premia-related covariance components are negatively correlated with one another, and with the REHTS measure.

6. Conclusions

In this paper we examine the significance of domestic and international factors in determining the slopes of the US, German and UK yield curves, and how the magnitude of their impact fluctuates over the business cycle. Our main finding is that at times of global financial turmoil, like the sterling exchange rate crisis of 1992, the Asian financial crisis of 1997 and the Russian debt crisis of 1998, these slopes respond mainly to international factors, presumably as global investors reallocate their bond portfolio holdings and local investors readjust their expectations about domestic interest rates. We also examine the decomposition of the covariances between the US, German and UK long-term interest rates. Our decomposition of the covariance between these government bond markets indicates that risk premia and/or contagion effects have played an important role during these periods, moving the covariance between the markets away from where we might have expected it to be if international bond rates were determined solely by the REHTS arbitrage.

Appendix A

The estimation of the term structure of interest rates[13]

The term structures of US Treasury zero coupon bonds are provided by the Bank of England. Here we provide a brief discussion of the relevant issues. $P_{i,t}^{G}$, i=1,...,n, is the price (clean price plus accrued interest) of an ith maturity bond at time t. The bond $P_{i,t}^{G}$ pays a stream of cash flows, c_{ij}, (including redemption payments) at times m_{ij}. The vector of discount bonds corresponding to the coupon-paying bonds can be estimated from the following non-linear model:

(A1) $$P_{i,t}^{G} = \sum_{j} c_{ij}\delta(m_{ij}, \boldsymbol{\beta}) + \varepsilon_{ij,} \quad i = 1,...,n$$

where $\delta(m_{ij}, \boldsymbol{\beta})$ is a parametric discount function with parameter vector $\boldsymbol{\beta} = (\beta_0, \beta_1, \beta_2, \beta_3, \tau_1, \tau_2)$.

The functional form selected by the Bank of England is based on the Svensson (1994, 1995) generalisation of the Nelson and Siegel (1987) model. According to Svensson the term structure of zero coupon yields is given by:

(A2) $$\begin{aligned} y(m,\boldsymbol{\beta}) &= \beta_0 \\ &+ \beta_1 \frac{1 - e^{-\frac{m}{\tau_1}}}{m/\tau_1} \\ &+ \beta_2 \left[\frac{1 - e^{-\frac{m}{\tau_1}}}{m/\tau_1} - e^{-\frac{m}{\tau_1}} \right] \\ &+ \beta_3 \left[\frac{1 - e^{-\frac{m}{\tau_2}}}{m/\tau_2} - e^{-\frac{m}{\tau_2}} \right] \end{aligned}$$

and the discount function is:

(A3) $$\delta(m,\boldsymbol{\beta}) = \exp\left(-\frac{y(m,\boldsymbol{\beta})}{100} m \right)$$

Equations (A2) and (A3) are substituted in equation (A1) and the parameter vector $\boldsymbol{\beta}$ is estimated via a non-linear maximisation algorithm.

---

[13] This appendix is largely based on the work undertaken by the Monetary Instruments and Markets division at the Bank of England. See Bianchi (1997) and Anderson et al. (1996) for more details.

Appendix B

Swap market data

The most common type of interest rate swap is the fixed-to-floating par swap. This is a contract between two counterparties to exchange future cash flows or equivalently to exchange interest rate risk positions. One party of the swap, namely the fixed payer, agrees to pay, on each payment day until the maturity of the swap, an amount equal to a fixed interest rate applied on a notional principal. In return, the fixed payer receives from the other counterparty, the floating payer, cash flows based on the same notional principal but calculated with respect to a floating interest rate, e.g. Libor. The payments of these cash flows usually occur either annually or semiannually.

The technique used to infer the prices of zero coupon bonds from swap rates is called bootstrapping and is based on the fact that interest rate swaps are par instruments with zero net present value. In the case of US dollars, where the swap cash flows occur annually, the prices of discount bonds implied by the swap market are given by:

(B1) $$b_{0,t} = \frac{1 - s_t \left(\sum_{i=1}^{t-1} \alpha_{i-1,i} b_{0,i} \right)}{1 + s_t \alpha_{t-1,t}}$$

where s_t is the swap rate, $i = 1,2,\ldots,t$ and the accrual factor is $\alpha_{i-1,i}$.[14] The only problem is that swaps are available only for one, two, three, four, five, seven and 10 years of maturity. Thus, a linear interpolation has to be used to get an estimate of the missing swap rates.

In the case of pound sterling swaps, where the swap cash flows occur semiannually, the calculations are slightly more complicated.[15] If the swaps make semiannual payments, then we have to use swap rates every half a year in order to calculate the zero bond prices for the corresponding period. Again a linear interpolation has to be used to get an estimate of the missing swap rates. The only swap rate we are not able to calculate using linear interpolation is the $s_{1.5}$ swap rate since the one-year swap rate is not available and the corresponding one-year rate available from the money market is quoted on a different basis. As a result an adjustment has to be made:

(B2) $$s_1 = \frac{1 - b_{0,1}}{\alpha_{0.0.5} b_{0,0.5} + \alpha_{0.5,1} b_{0,1}}$$

and $s_{1.5}$ can be calculated by interpolating between s_1 and s_2.

Finally, the zero bond prices can be calculated using the bootstrap method as in equation (B1) but now the index *i* in the summation is being done semiannually such that i = 1, 1.5, 2, 2.5, …, t.

Based on those zero coupon bond prices, we can estimate the implied annualised yields as:[16]

(B3) $$r_{0,t} = \left(\frac{1}{b_{0,t}} \right)^{-\alpha_{0,t}} - 1$$

---

[14] In the case of US dollar interest rate swaps, the accrual factor is defined as $\alpha_{i-1,i} = \frac{30}{360}$.

[15] In the case of sterling swap markets, the swap day-count convention is 365 days per year. Thus, the accrual factor is defined as $\alpha_{i-1,i} = \frac{t_i - t_{i-1}}{365}$.

[16] The accrual factors now refer to bonds and are defined a $\alpha_{i-1,i} = \frac{t_i - t_{i-1}}{365}$.

One-year forward rates can be estimated by:

(B4) $$f_{0,t,t+12m} = \left(\frac{b_{0,t}}{b_{0,t+12m}} \right)^{-\alpha_{t,t+12m}} - 1$$

Bibliography

Ammer, J and J Mei (1996): "Measuring international economic linkages with stock market data". Journal of Finance, 51(5), pp. 1743-63, December.

Anderson, N, F Breedon, A Deacon, M Derry and G Murphy (1996): *Estimating and interpreting the yield curve.* John Wiley & Sons, London.

Bianchi, M (1997): *Estimation of forward yield curves from conventional and index-linked bonds.* Mimeo, Bank of England.

Campbell, J Y and J Ammer (1993): "What moves the stock and bond markets? A variance decomposition for long-term asset returns". Journal of Finance; 48(1), pp. 3-37, March.

Campbell, J Y and R J Shiller (1987): "Cointegration and tests of present value models". Journal of Political Economy; 95, pp. 1062-88.

Campbell, J Y and R J Shiller (1988): "Stock prices, earnings, and expected dividends". Journal of Finance; 43(3), pp. 661-76 July.

Christiansen, H and C Pigott (1997): "Long-term interest rates in globalised markets". OECD Working Paper Series, Paris.

Dahlquist, M, P Hördahl and P Sellin (1999): "Measuring international volatility spillovers". This volume.

Engle, R F, T Ito and W Lin (1990): "Meteor showers or heat waves? Heteroskedastic intra-daily volatility in the foreign exchange market". Econometrica, 58, pp. 525-42.

Eun, C S and S Shim (1989): "International transmission of stock market movements". Journal of Financial and Quantitative Analysis, 24, pp. 241-56.

Evans, M D D and K K Lewis (1994): "Do stationary premia explain it all? Evidence from the term structure". Journal of Monetary Economics, 33, pp. 285-318.

King, M A and S Wadhwani (1990): "Transmission of volatility between stock markets". Review of Financial Studies, 3(1), pp. 5-33.

Koch, P D and T W Koch (1991): "Evolution in dynamic linkages across daily national stock indexes". Journal of International Money and Finance, 10(2), pp. 231-51, June.

Koutmos, G and G G Booth (1995): "Asymmetric volatility transmission in international stock markets". Journal of International Money and Finance, 14, pp. 747-62.

Lin, W, R F Engle and T Ito (1994): "Do bulls and bears move across borders? International transmission of stock returns and volatility". Review of Financial Studies, 7, pp. 507-38.

Minton, B A (1997): "An empirical examination of basic valuation models for plain vanilla U.S. interest rate swaps". Journal of Financial Economics, 44, pp. 251-77.

Nelson, C R and A F Siegel (1987): "Parsimonious Modeling of Yield Curves". Journal of Business, 60(4), pp. 473-89, October.

Shiller, R J, F Konya and Y Tsutsui (1991): "Investor behaviour in the October 1987 stock market crash: The case of Japan". Journal of the Japanese and International Economy, 5(1), pp. 1-13, March.

Shiller, R J and A E Beltratti (1992): "Stock prices and bond yields: Can their comovements be explained in terms of present value models?" Journal of Monetary Economics, 30(1), pp. 25-46, October.

Sims, C A (1980): "Macroeconomics and reality". Econometrica, 48(1), pp. 1-48, January.

Solnik, B, C Boucrelle and Y Le Fur (1996): "International market correlation and volatility". Financial Analysts' Journal, pp. 17-34, September/October.

Sun, T S, S Sundaresun and C Wang (1993): “Interest rates swaps. An empirical investigation”. Journal of Financial Economics, 34, pp. 77-99.

Svensson, L (1994): “Estimating and interpreting forward rates: Sweden 1992–1994”. Working paper 114, International Monetary Fund.

Svensson, L (1995): “Estimating forward rates with the extended Nelson and Siegel method”. Quarterly Review, Sveriges Riksbank.

Evaluating "correlation breakdowns" during periods of market volatility

Mico Loretan and William B English[1]

1. Introduction

In order to measure and manage market risks, financial analysts take account of the variability and correlation of the returns on assets held in their portfolios. One difficulty they encounter in doing so is that in periods of heightened market volatility, correlations between asset returns can differ substantially from those seen in quieter markets. The problem of "correlation breakdown" during periods of greater volatility is well known. For example, the former global risk manager of a major financial firm notes that, "during major market events, correlations change dramatically" (Bookstaber (1997)). A recent example of this phenomenon occurred following the Russian default in August 1998. One prominent money center bank attributed larger than expected losses in late summer and early fall last year to higher volatility, illiquidity and "breakdowns in historical correlations" (JP Morgan (1999)). Indeed, a comprehensive study found that the average correlation between five-day changes in yield spreads for 26 instruments in 10 economies rose from 0.11 in the first half of 1998 to 0.37 between mid-August and mid-September, but then fell back to 0.12 after mid-October (Bank for International Settlements (1999), Table A18).

It is tempting to explain the increased correlation of returns during hectic market periods as the result of a shift in the joint distribution of asset returns owing to contagion of some markets by others, the particular nature of the shocks, or changes in market structures and practices.[2] However, unless one has a model of when such periods are likely to arise, or at least how often, and what particular pattern of correlations will ensue, this approach makes it extraordinarily difficult to manage risk because the relationship between asset returns in some future situations is essentially unknown.[3]

Moreover, the inference that changes in measured correlations imply that the joint distribution of asset returns changes in volatile periods may not be warranted. Even if the behavior of asset returns is governed by an unchanged process, one would expect a link between volatility and measures of correlation. Indeed, a model of asset returns as simple as the bivariate normal can explain why periods of increased (sampling) volatility will also be periods of relatively high (sampling) correlations. The possible importance for economics and finance of this result has only been realized recently (Ronn (1995); Boyer, Gibson and Loretan (1999); Forbes and Rigobon (1999)).[4] In this paper, we demonstrate that a significant portion of shifts in correlations over time – including those that occurred in the fall of 1998 – may reflect nothing more than the predictable effect of differences in sample volatilities on measured correlations, rather than breaks in the data generating process for asset returns.

To explore this possibility, we select three asset classes – equities, bonds and foreign exchange – in two representative countries and look at the quarterly correlations between daily returns over the

---

1 The analysis and conclusions in this paper are those of the authors and do not indicate concurrence by other members of the research staff, by the Board of Governors, or by the Federal Reserve Banks. We thank Jim Clouse, Mike Gibson, Michael Gordy, Brian Madigan, Matt Prisker and Vince Reinhart for helpful comments and discussions. All remaining errors are ours.

2 Recent discussions of possible routes for contagion include Drazen (1998), Eichengreen, Rose and Wyplosz (1996) and Gerlach and Smets (1995). The CGFS report on the events of the fall of 1998 (Bank for International Settlements (1999)) presents a narrative account of how the effects of shocks were reinforced and spread to other markets by market practices.

3 One advance along these lines is the structural model of contagion-like transmission of shocks presented in Kodres and Pritsker (1999).

4 Ronn (1995) attributes the insight to a conference discussion by Stambaugh.

1990s. Our calculations suggest that quarters with high correlations tend also to be quarters with higher than average volatility. Moreover, actual correlations during periods of relatively high volatility appear to be fairly close to the correlations one would expect conditional on the level of volatility and based on an unchanged process for asset returns. Our findings generalize the results reported for stock prices in Forbes and Rigobon (1999), and suggest that correlation breakdowns may reflect time-varying volatility of financial markets rather than a change in the relationships between asset returns.

Since the link between market volatility and in-sample correlations between asset prices appears to be empirically important, we go on to consider the implications of this link for risk management practices, the supervision of financial firms and the conduct of monetary policy. We note that the use of data for a relatively short period when calculating correlations for use in risk management models may lead to poor measurements of market risks. We also point to the need to use appropriate conditional correlations when examining the riskiness of a portfolio under high volatility scenarios. Finally, because monetary policy can affect the volatility of markets, monetary policymakers may find it useful to incorporate the effect of unexpected changes in policy on market participants' assessment of their risk exposures. Indeed, some monetary policymakers may, in practice, make this link: there is some evidence that monetary policy in the United States was initially adjusted relatively slowly in early 1994 because of concern that the long period of interest rate stability that preceded the rate hike had led some market participants to underestimate the riskiness of their positions.

2. The theoretical link between volatility and correlation

To see the link between volatility and correlation, consider the unrealistically simple case of two random variables, x and y, that are independently and identically distributed bivariate normal, with means equal to zero, variances equal to unity and a correlation of 0.5. A large sample of draws of such (x,y) pairs is shown in Figure 1. Now consider splitting the full sample into two subsamples based on the value of x: a "low volatility" subsample, including all (x,y) pairs with an absolute value of x less than 1.96; and a "high volatility" subsample, including all (x,y) pairs with an absolute value of x greater than or equal to 1.96.[5] Intuitively, the effect of trimming the ends off the joint distribution in the low volatility subsample should be to reduce the sample correlation between x and y. By contrast, the correlation for the high volatility subsample should be enhanced because the support of its distribution is disjointed, with one portion picking up the large positive values of both variables while the other portion of the distribution picks up the large negative values of the variables. Indeed, as noted in the figure, the correlation for the high volatility subsample is 0.81, while that for the low volatility sample is 0.45. Note that the correlation in the latter subsample is close to the population value of 0.5; this latter result may not be surprising since the low volatility subsample includes 95% of the data.

2.1 Theoretical result

This intuitive result can be derived formally. Boyer, Gibson and Loretan (1999) provide the following theorem:

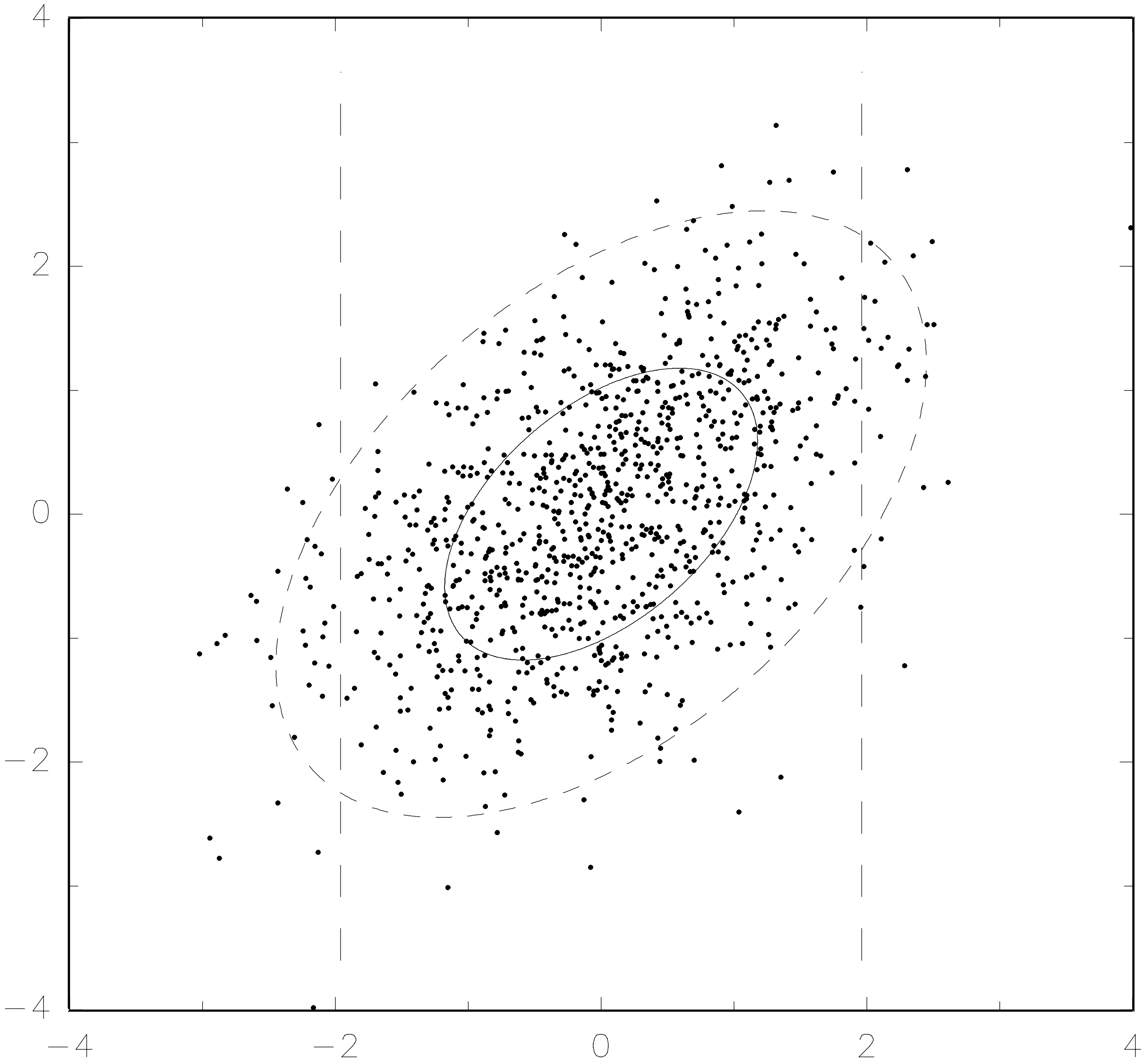
Theorem: consider a pair of bivariate normal random variables x and y with variances σ_x^2 and σ_y^2, respectively, and covariance σ_{xy}. Let ρ $(= \sigma_{xy}/(\sigma_x\sigma_y))$ be the unconditional correlation between x and y. The correlation between x and y conditional on an event $x \in A$, for any $A \subset \mathbb{R}$ with $0 < \mathrm{Prob}(A) < 1$, is given by:

(1) $$\rho_A = \rho\left(\rho^2 + (1-\rho^2)\frac{Var(x)}{Var(x|x\in A)}\right)^{-1/2}$$

---

5 The marginal distributions of x and y are (univariate) standard normal, hence $\mathrm{Prob}(|x|>1.96)$ is equal to 0.05.

Figure 1
Bivariate normal random numbers, $\rho=0.5$



$\rho\big((x,y) \mid |x|<1.96\big)=0.45, \quad \rho\big((x,y) \mid |x|\geqq 1.96\big)=0.81$

Proof:[6] Let u and v be two independent standard normal random variables. Now construct two bivariate normal random variables x and y with means μ_x and μ_y, respectively,

variances σ_x and σ_y, respectively, and correlation coefficient ρ:

(2) $$x = \mu_x + \sigma_x u$$

(3) $$\begin{aligned} y &= \mu_y + \rho\sigma_y u + \sqrt{1-\rho^2}\,\sigma_y v \\ &= \mu_y + (\rho\sigma_y/\sigma_x)(x-\mu_x) + \sqrt{1-\rho^2}\,\sigma_y v \end{aligned}$$

---

6 A more detailed version of the proof can be found in Boyer, Gibson and Loretan (1999). Their proof depends on the fact that bivariate normal random variables can each be written as a weighted average of the other and an independent component that is also normally distributed. See Goldberger (1991), p. 75.

Consider any event $x \in A$ such that $0 < \text{Prob}(x \in A) < 1$. By definition, the conditional correlation coefficient between x and y, ρ_A, is given by:

(4) $$\rho_A = \frac{Cov(x,y \mid x \in A)}{\sqrt{Var(x \mid x \in A)}\sqrt{Var(y \mid x \in A)}}$$

By substituting for u in (3) using equation (2), then substituting the resulting expression for y into (4), and using the fact that x and v are independent by construction, one can rewrite this as:

(5) $$\rho_A = \frac{(\rho \sigma_y / \sigma_x) Var(x \mid x \in A)}{\sqrt{Var(x \mid x \in A)}\sqrt{(\rho^2 \sigma_y^2 / \sigma_x^2) Var(x \mid x \in A) + (1 - \rho^2)\sigma_y^2}}$$

which can, in turn, be simplified to yield the expression in (1).

Thus, the conditional correlation between x and y is larger (smaller) than ρ in absolute value if the conditional variance of x given $x \in A$ is larger (smaller) than the unconditional variance of x.[7]

2.2 Some generalizations

This theorem is based on several assumptions that are unrealistic in empirical practice, such as that the data are i.i.d. and are drawn from a bivariate normal distribution. In the present case, bivariate normality of x and y is used – see equation (3) in the proof above – only to re-express the variable y as an affine function of x, $\mu_y + (\rho\sigma_y/\sigma_x)(x-\mu_x)$, plus a component that is independent of x, $\sqrt{1-\rho^2}\,\sigma_y^2 \nu$. Therefore, the main result of the theorem is not limited to cases where the data are bivariate normal, but holds in any situation where y can be stated as a linear (or, more generally, an affine) function of x plus an independent component (the "error term"), a framework which encompasses the familiar bivariate linear regression model with independent (but not necessarily normally distributed) errors.

Economic data are often observed as time series, and it is of interest to understand how measured correlations are affected by sampling variability in the data. Time series also pose the question of how serial dependence in the data affects the correlations. Assuming the general linear regression model, $y = \beta x_t + u_t$, with $Cov(x_t, u_t) = 0$ and $t = 1,2,\ldots$, one may write the sampling correlation coefficient between x and y, for a sample of size n, as

(6) $$Corr_n(x,y) = \frac{Cov_n(x,y)}{\sqrt{Var_n(x)}\sqrt{Var_n(y)}}$$

which can be rewritten as

(7) $$Corr_n(x,y) = \frac{\beta Var_n(x) + Cov_n(x,u)}{\sqrt{Var_n(x)}\sqrt{\beta^2 Var_n(x) + Var_n(u) + \beta Cov_n(x,u)}}$$

where the subscript n denotes sampling, as opposed to population, moments.[8]

Of primary interest to our paper is how this correlation coefficient will vary across subsamples of time. It will differ from the population moment for two reasons: the sampling covariance between x_t

---

[7] Henri Pagès has provided the following heuristic interpretation of the result given in (1): if conditioning on an event $x \in A$ brings about an increase in the conditional variance of x, $Var(x \mid x0A)$, it also raises the population conditional correlation between x and y because of a concomitant increase in the ratio $Var(x|x0A)/Var(x)$, which can be rewritten as $(Var(v)/Var(x))(Var(x|x0A)/Var(v)$, where the first term is a constant and the second term is a signal to noise ratio; it is this increase in the signal to noise ratio that raises the conditional correlation.

[8] The connection from equation (6) to (1) is made by setting $\beta = \rho\sigma_y/\sigma_x$ and $u_t = \sqrt{1-\rho^2}\,\sigma_y \nu_t$, and by dividing the numerator and denominator on the right-hand side of (6) by $Var(x) = \sigma_x^2$, the population unconditional variance of x.

and the “error” term u_t may be non-zero, or the sampling variance of u_t may be time-varying (and correlated with $Var_n (x)$).

In financial time series, we often find that the mean of y_t is close to a linear function of x_t, and that $Cov_n (x_t ,u_t) \approx 0$ is a reasonable assumption to make. However, even if the levels of x and u are approximately uncorrelated, their variances may well be serially, as well as contemporaneously, correlated. Hence, the term $Var_n (u)$ may move systematically across subsamples with the sampling variance of x. Suppose, for example, that $\beta > 0$ and that the contemporaneous volatilities of x and u (and hence the contemporaneous volatilities of x and y) are positively correlated. Then, time intervals exhibiting a high sampling variability of x will also tend to have larger than average values for $Var_n (u)$. As a result, the *sampling* correlation between x and y will tend to deviate *less* from its population value, on average, than would be suggested by equation (1). (The possible practical importance of contemporaneous dependence in volatilities is discussed below; see footnote 17.)

While the preceding discussion establishes that the simple expression stated in equation (1) for the relationship between conditional and unconditional correlations may have to be modified suitably when some of the maintained assumptions of the theorem are not met by the data, it is clear that conditioning on volatility will, in general, have strong systematic effects on the correlation between x and y.

2.3 A simple example

As an example of a time series application of that theorem, consider subdividing a bivariate time series (x_t ,y_t) that is observed daily into equally sized subsamples (“quarters”) of 60 daily observations each, and then ordering the quarters by the level of the within-quarter variance of x. For each subsample, we may also calculate the correlation between x and y. Table 1 shows the results of such an exercise under the assumption that x and y are i.i.d. bivariate normal with unit variances and a population correlation coefficient equal to 0.5 (as in Figure 1). The rows of the table show ranges for the ratio of the quarterly variance in x to its population value, while the columns show the distribution of the values of the quarterly correlation given the ranges. For values of the within-quarter variance of x close to its population value (0.9 to 1.1), the median value of the correlation is 0.50, although the range of values is fairly wide, with a 90% confidence interval running from 0.34 to 0.64. However, for quarters with in-sample variance of x between 1.7 and 1.9 times the population value, the median correlation is 0.61, with the 90% confidence interval running from 0.48 to 0.72.

Table 1
In-sample correlations when conditioning on volatility

Range of variances of x relative to its population value	Conditional correlation of x and y		
	Bottom 5%	Median	Top 5%
0.3–0.5	0.17	0.36	0.53
0.5–0.7	0.24	0.43	0.58
0.7–0.9	0.29	0.47	0.61
0.9–1.1	0.34	0.50	0.64
1.1–1.3	0.38	0.54	0.67
1.3–1.5	0.41	0.57	0.69
1.5–1.7	0.45	0.59	0.71
1.7–1.9	0.48	0.61	0.72

Note: The values of x and y are i.i.d. bivariate normal with a population correlation of 0.5. Reported values for the $Corr(x,y)$ are based on 2.5 million random draws of 60 observations (“quarters”). There were too few observations with the variance of x less than 0.3 or greater than 1.9 times its population value for values of $Corr(x,y)$ to be reported with confidence.

3. An empirical application

3.1 The data

In order to assess the empirical importance of the relationship between volatility and correlation over time, we need to study specific pairs of asset prices. We consider a relatively broad set of assets, rather than focus on a single type of asset (e.g. equity prices, as in Forbes and Rigobon (1999)). As shown in Table 2, we settled on equities, bonds and foreign exchange. The Financial Times and DAX stock price indexes are as of the close of the stock markets in London and Frankfurt, respectively, and are taken from Bloomberg. The German and British government bond yields are those on 10-year instruments. They are also as of market close and are from Bloomberg. The dollar/mark and dollar/yen exchange rates are those prevailing around noon in the New York market and are collected by Federal Reserve staff. We selected these particular series because they represent large and liquid markets and the data reflect market conditions at roughly the same time, and so we do not have to be concerned about the implications of non-synchronous data collection.[9]

Table 2
Data series used

Asset prices	Quote time	Quote location	Source
Equity prices			
Financial Times 100	Market close	London	Bloomberg
DAX	Market close	Frankfurt	Bloomberg
Government bond yields			
UK 10-year note	Market close	London	Bloomberg
German 10-year note	Market close	Frankfurt	Bloomberg
Exchange rates			
US dollar / Japanese yen	About noon New York time	New York	Federal Reserve
US dollar / Deutsche mark	About noon New York time	New York	Federal Reserve

Note: The London and Frankfurt markets now close at the same time, although in the past their closing times have differed by one hour.

The returns on foreign exchange and equity holdings are simply the daily percentage changes in their respective prices. Calculating the returns on government bonds is more complicated, since the available data relate to bond yields rather than bond prices. The return we use is an estimate of the percentage daily gain or loss from holding the 10-year bellwether government bonds, based on the reported yields and under the assumption that the bonds have maturities of exactly 10 years, have coupon payments twice a year, and are trading at par.[10]

Figures 2–4 show time series plots of the within-quarter variances (panels a and b) and correlations (panel c) of daily returns for the three pairs of assets. In the case of stock prices (Figure 2), it is clear that last fall was a period of high volatility and, just as the theorem presented earlier would suggest, there was a high correlation between the two returns. The returns on bond investments were also somewhat volatile last fall (Figure 3), and the correlation between the two returns in 1998 Q3 and 1998 Q4 was at the high end of its range. By contrast, movements in the dollar/yen and dollar/mark

[9] For a discussion of the problems associated with non-synchronous data collection, see RiskMetrics (1996), pp. 184–96.

[10] The approximation is excellent for small changes in yields on bonds trading near par. Even for large movements in yields on bonds priced far from par, the approximation is fairly good. For example, on October 9, 1998 (the day of the largest one-day loss on UK bonds in the sample), the UK 10-year bond maturing in October 2008 was selling near 130. Based on bond price and yield data from the *Financial Times*, the actual loss on the bond for that day was 2.33%, while the approximation yields a loss of 2.55%.

exchange rates were not particularly highly correlated last fall (Figure 4), despite the extraordinarily high volatility in the dollar/yen rate in 1998 Q4.

Figure 2
Within−quarter variances and correlations, stock market indexes

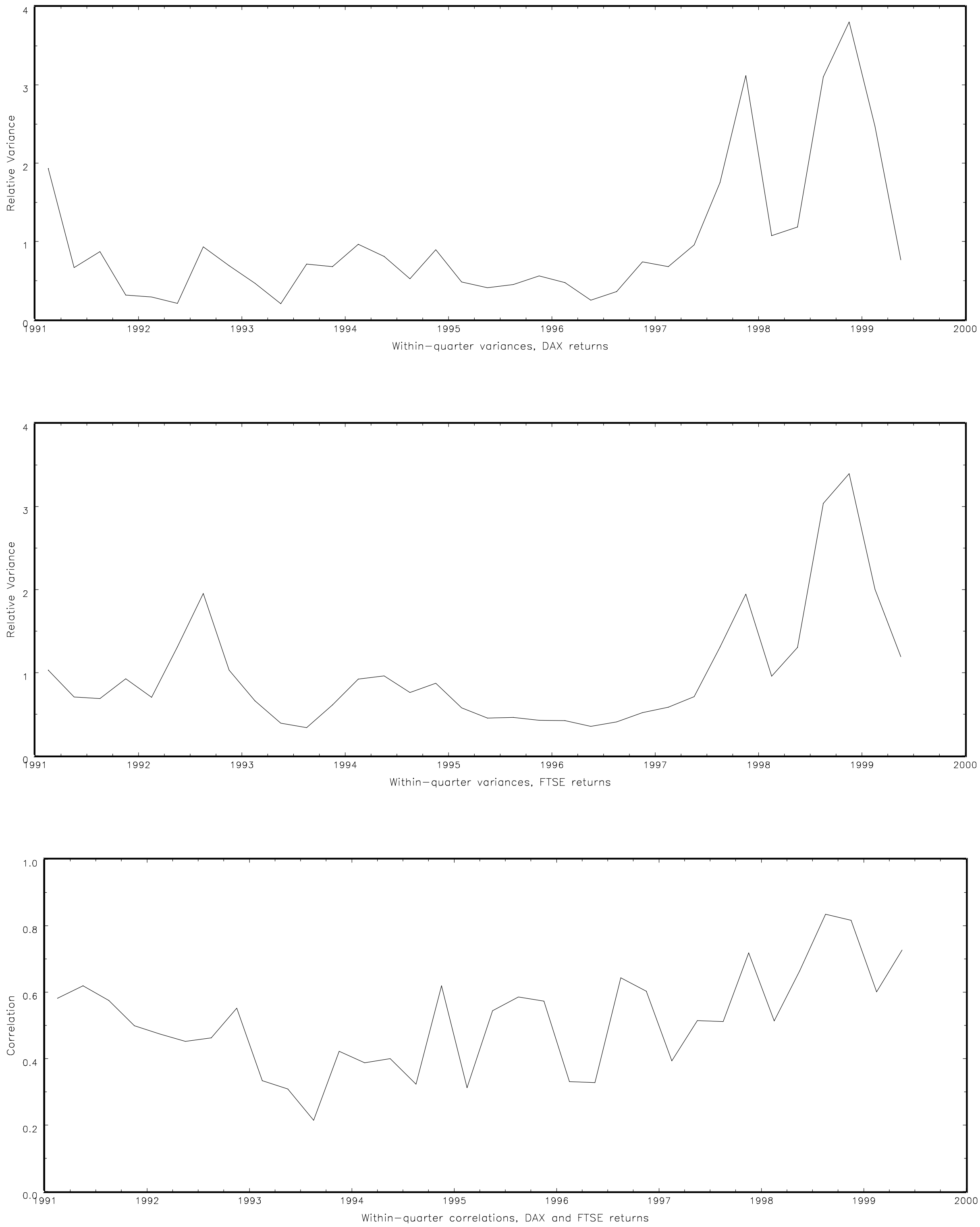


Figure 3
Within-quarter variances and correlations, bond returns

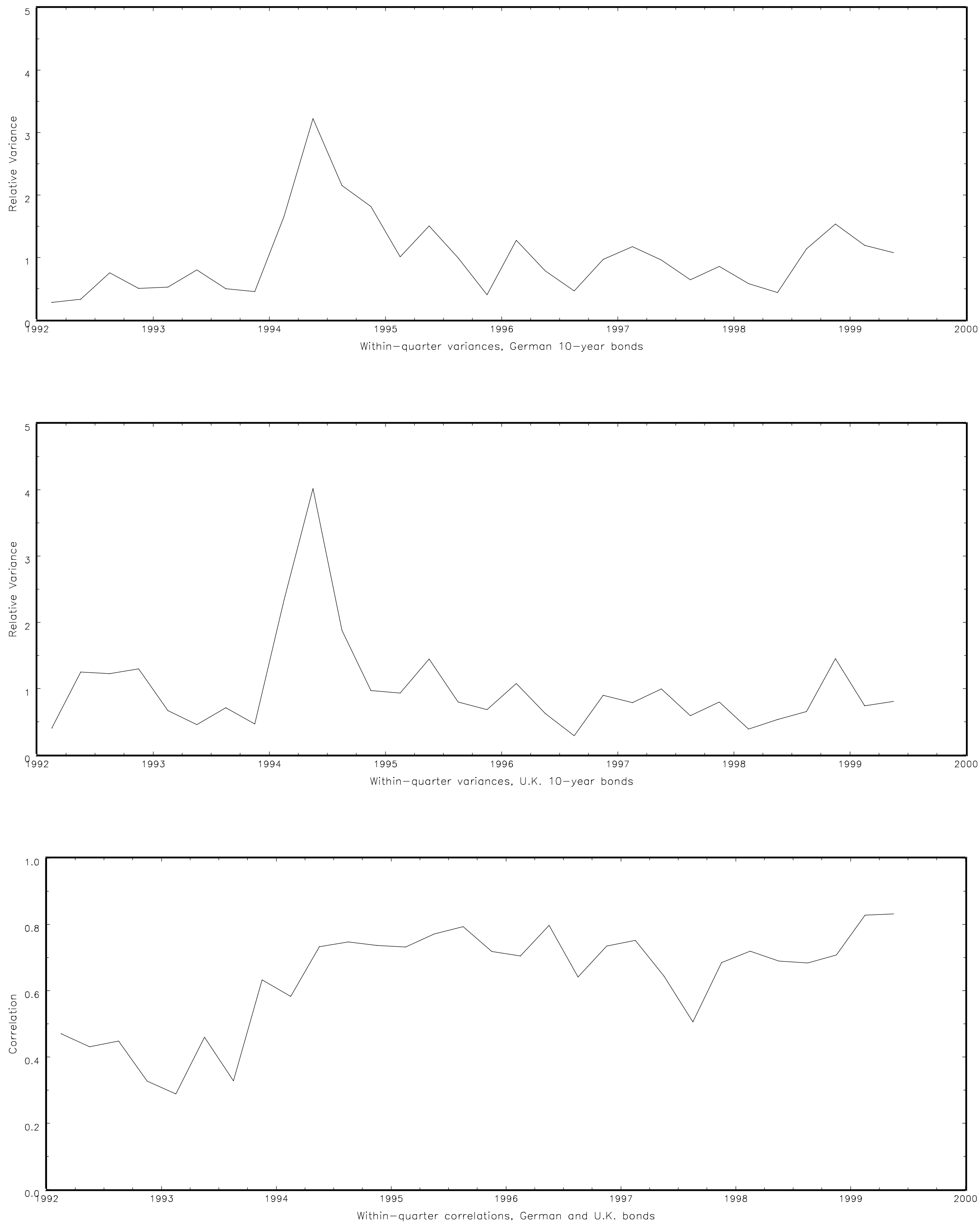
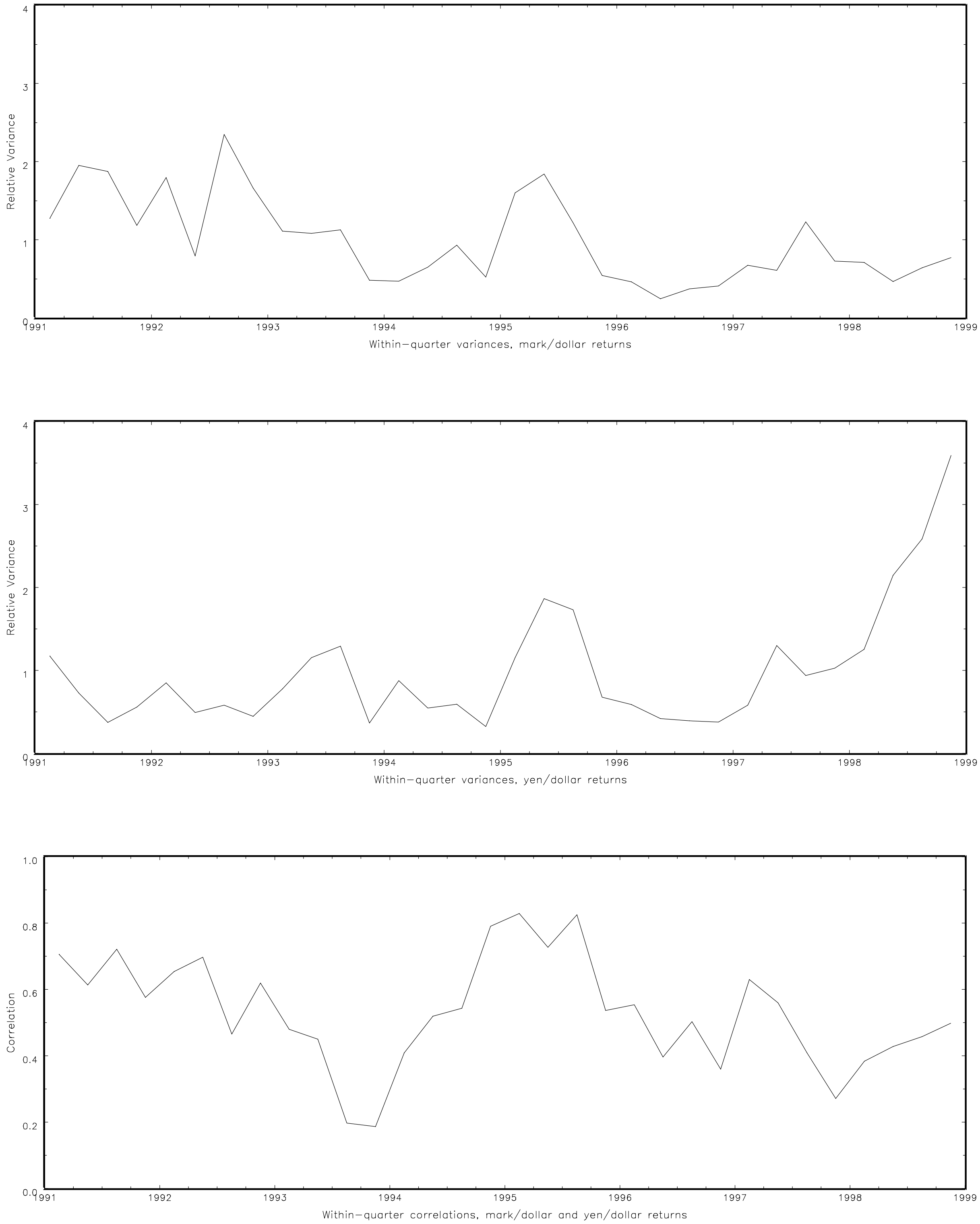


Figure 4
Within–quarter variances and correlations, exchange rate returns



3.2 Using the theorem

Before using the theorem to try to explain the variation in quarterly correlations between returns, we need to examine whether the data satisfy its assumptions to ensure that its use is appropriate. Then, for each pair of returns, we need to determine the anticipated relationship between volatility and correlation, based on the actual variances and correlations of the series, and compare the actual data to that anticipated relationship.

Figure 5
Nonparametric estimates of joint distribution of returns

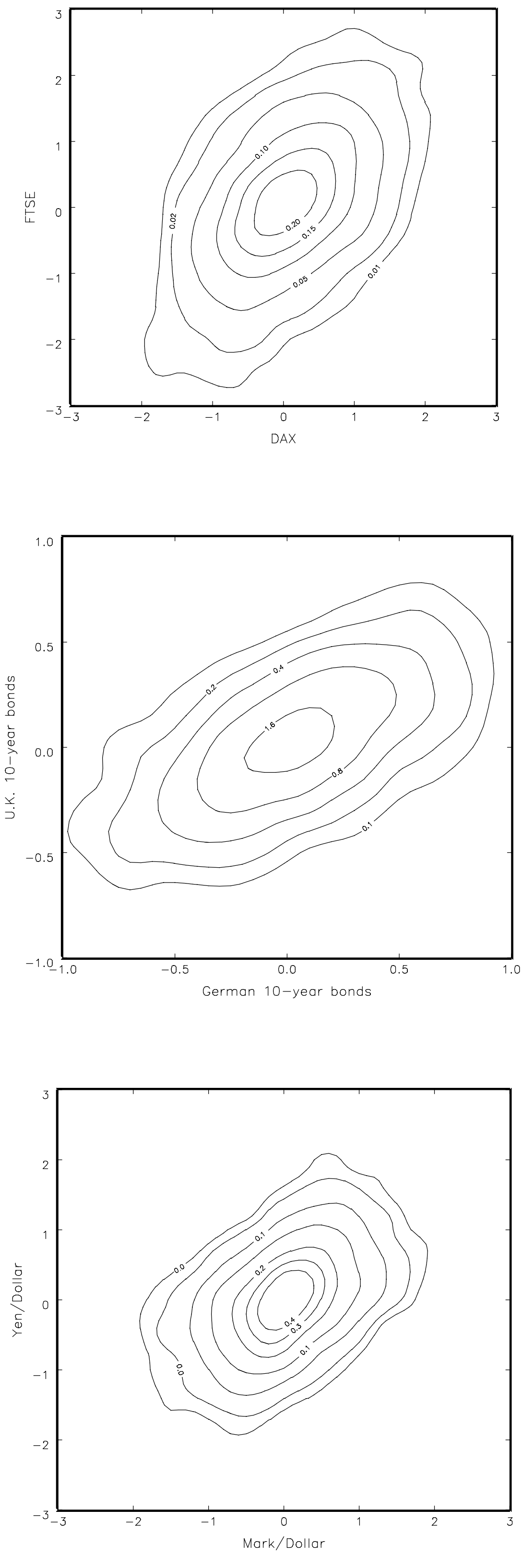


Figure 5 shows non-parametrically estimated level curves of the joint distributions of the pairs of asset returns.[11] These concentric curves are loci of constant height of the joint densities, and so they show the shape of the distribution of the observations. Recall that the theorem's main requirements are those of a linear regression model, which are satisfied if the joint distribution of the data is elliptic, that is, if the level curves of the joint density are ellipses (see Spanos (1986), pp. 457–8). The estimated level curves appear to be reasonably close to elliptic, although those for the exchange rates are somewhat more "rectangular" than the other two sets. We view these level curves as suggesting that the assumption of an elliptical distribution is reasonable for our empirical work, and hence that it is worthwhile to proceed comparing the empirical variance/correlation pairs with values predicted by that theorem.

To evaluate the importance of the theoretical link between volatility and correlation, we plot in Figure 6 the quarterly in-sample correlations against the in-sample volatility of one of the two asset returns.[12] In all three cases, a generally increasing relationship between conditional variances and conditional correlations is observable. However, the data also show a considerable dispersion in the in-sample correlation for a given level of volatility. In order to assess how close the points are to the locations indicated by the theorem, we also show in Figure 6 the theoretical relationship between asset return volatility and the correlation between asset returns, the dashed line (derived from equation (1)), and a 90% confidence contour around this theoretical locus, derived under the maintained assumptions that the data are i.i.d. bivariate normal, and that the population correlation is equal to the full-sample empirical correlation.[13]

The theoretical relationships appear to fit the data fairly well. In the case of equity prices, the increase in correlation late last year was very large and, as shown by the two points to the top right in the chart, these relatively high correlations were roughly consistent with what the theorem would lead one to expect given the increase in volatility at that time. The events of last fall left a much smaller imprint on the correlations between returns on government bonds and foreign exchange. In the case of foreign exchange, this may not be surprising given that the volatility of the dollar/mark exchange rate was not elevated. Over the entire period plotted, however, the empirical relationship between volatility and correlation seems to fit the theorem fairly well, although, in the case of the bond and foreign exchange returns, the fractions of observations falling outside the 90% confidence contours considerably exceed 10%.[14]

However, the stated 90% confidence intervals in Figure 6 will not be correct if the data are not well approximated by a bivariate normal distribution. For example, it is well known that the (unconditional) distribution of asset returns is strongly leptokurtic, resulting in far more "outlier" observations than one would expect under normality.[15] One way to obtain improved confidence intervals is to use a bootstrap. We select random samples of a quarter's worth of observations (60 pairs of returns) from

---

[11] The non-parametric estimates of the joint densities are based on a bivariate normal kernel and a standard window width (Silverman (1986), pp. 86–7).

[12] The correlations could be plotted relative to the volatility of either return, but we have chosen the volatility of the German asset as the variable for the *x*-axis in all three cases. While this choice is immaterial theoretically, in the cases of the bond and foreign exchange returns, the results are somewhat better when the German asset volatility is selected. Note that the variances of the German asset returns have been expressed relative to their full-sample values.

[13] Ronn (1995) plots average measures of comovement stratified by volatility for a number of interest rate measures and (separately) for a large number of US equity prices. He finds that, consistent with the theorem, large moves in asset prices are associated with a higher average degree of comovement. However, he does not try to match the empirical relationships with those implied by the theorem.

[14] The confidence contours are shown over a relatively narrow range of quarterly variances because, under the assumption of an i.i.d. bivariate normal distribution of returns, there are too few observations outside this range (given our choice of 2.5 million repetitions) to allow the calculation of confidence intervals. The number of points on the left and right of the confidence contours shown reflects the fact that the actual distribution of returns has fatter tails than does the normal, resulting in greater dispersion of sampling variances.

[15] See, for example, Mandelbrot (1963). For more recent discussions, see Jansen and de Vries (1991) and Loretan and Phillips (1994).

the actual data series (with replacement) and calculate the correlation and variance for each sample. By repeatedly sampling the data, we can trace out the median value of the correlation as well as 90%

Figure 6
Scatterplots of quarterly variances vs. quarterly correlations, normality—based confidence bands

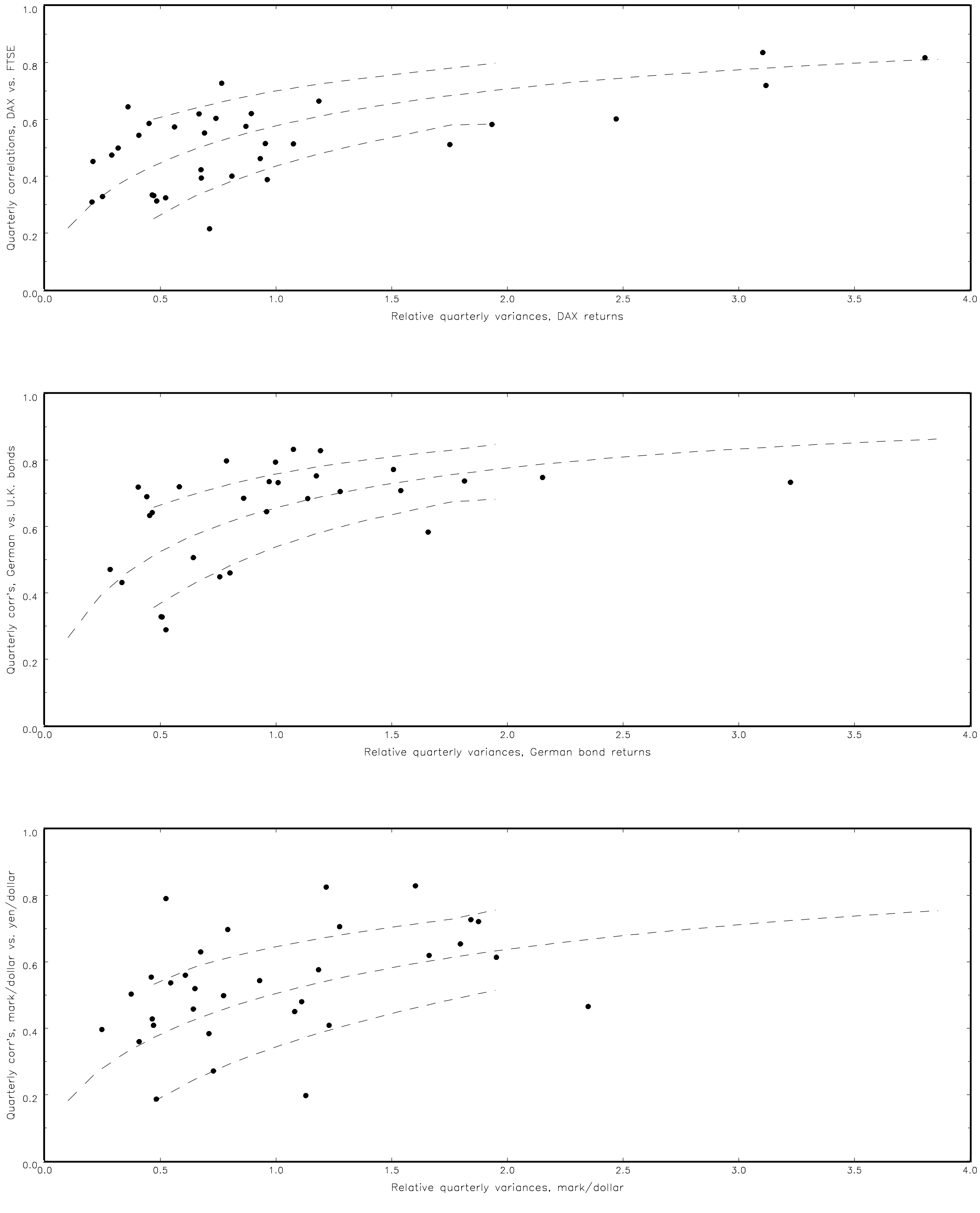
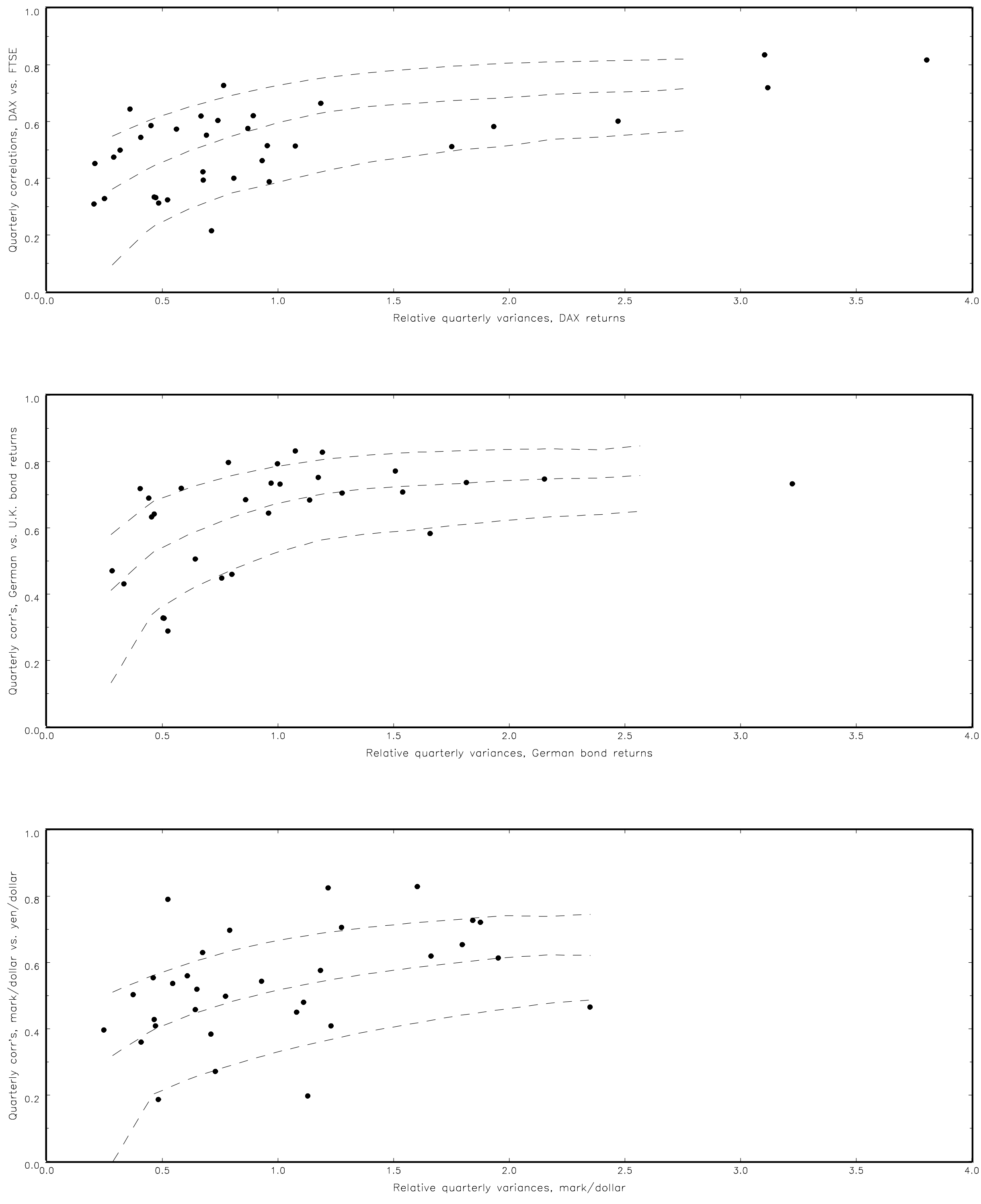


Figure 7
Quarterly variances vs. quarterly correlations,
bootstrapped confidence bands



confidence intervals based on the actual distributions of the data series.[16] These Monte Carlo results are shown in Figure 7.

[16] This bootstrap procedure preserves the contemporaneous correlation structure of the data, as well as the unconditionally heavy-tailed nature of the distributions, but it does not take account of serial dependence features such as GARCH which, as discussed in footnote 14, appear to be present in the data.

The improved methodology yields confidence contours that encompass a larger fraction of the quarterly data points.[17] It appears that the equity data fit the theory relatively well, with only three of the 34 observations outside the 90% confidence contours. The bond return volatilities and correlations also appear to be roughly what one would expect given the theorem, although with some evidence of a larger than expected clustering of observations to the upper left of the chart. The foreign exchange returns generally match the upward slope predicted by the theorem, but the range of correlations still appears to be considerably wider than would be expected. The three outlier observations at the top of this panel are from 1994 Q4 to 1995 Q3, that is, the period during and after the Mexican crisis of December 1994. The location of these points may suggest that the sharp fluctuations of the dollar against the mark and yen that occurred following the Mexican crisis, and the associated increase in the correlation of these asset returns relative to long-term norms, may have been caused by a genuine, though temporary, change in the data generating process.[18] For example, there were several episodes of concerted central bank intervention during this period, which would tend to boost daily correlations irrespective of changes in within-quarter volatility.

3.3 Summary

While there is some evidence in the case of foreign exchange suggesting the possibility of a temporary change in correlations following the Mexican crisis in late 1994, in general the link between high market volatility and high correlations between asset returns is remarkably close to what the theorem would suggest.[19] While a more comprehensive test of the proposition of stationarity, including a broader array of asset prices, is beyond the scope of this paper, our results suggest that one should not be too quick to conclude that correlation breakdowns, including those observed last year, represent true changes in the distribution of asset returns. Rather, they may be nothing more than the predictable consequences of observing certain (low probability) draws from an unchanged distribution. These results need not imply that "contagion" does not occur; rather, they suggest that if one defines contagion to mean elevated correlations between asset returns, then contagion is a natural by-product of temporal variation in volatilities.

3.4 Implications

The statistical link between the volatility and correlation of asset returns discussed here has important implications for the evaluation of portfolio risk by market participants and investors, for the supervision of financial firms' risk management practices, and for monetary policy.

In empirical practice, risk managers sometimes use data from a relatively short interval when calculating correlations and volatilities for use in risk management models. For example, one major banking company reports that they use the most recent 264 trading days' changes in market prices in their calculations of value at risk, or VaR (Chase Manhattan (1999), p. 36). RiskMetrics uses 550 daily

---

[17] The bootstrap also reveals that the location of the median correlation coefficient, for a given value of $Var_n(x)/Var(x)$, is (slightly) below the value predicted by equation 1 when $Var_n(x)/Var(x)$ is large, say greater than 2.5. This finding is consistent with our conjecture, advanced in Section 2 above, that a positive contemporaneous correlation between the volatilities of x and u could bring about lower bivariate correlations between the returns, on average, than the equation would suggest whenever $Var_n(x)$ – and hence $Var_n(u)$ – is large. We caution that the discrepancy we detect between the bootstrapped median value and the value predicted by equation (1) for the (subsample) correlations is quite small in all cases, and does not exceed 0.05. Hence, while the dependence between volatilities may bring about a slight deviation from the relationship stated in equation (1), the equation is still very useful for predicting the average location of the subsample correlations.

[18] Recall also that the estimated joint distribution of returns on foreign exchange shown in Figure 5 appeared to be less elliptical than those of the equity and bond returns.

[19] Our results are based on the volatility of asset returns with no distinction made between increases and decreases. In a related study, Longin and Solnik (1998) find that measured correlations between equity returns in different countries behave as the theorem would suggest when there are large positive stock market returns but are higher than the theorem would suggest when there are large negative returns. We leave an examination of this issue for future research.

return observations in the calculation of variances and correlations of returns, but because exponentially declining weights are applied, the effective number of daily returns employed is just 75 for estimates of daily correlations and volatilities and 150 for monthly values (RiskMetrics (1996), Table 5.9, p. 100). The use of a relatively short period for these calculations has some desirable features. Since financial markets can change over time, one may not want to depend on data from the distant past.[20] Moreover, the emphasis RiskMetrics puts on recent data allows it to take account of time-varying volatility, which appears to be a feature of actual returns (RiskMetrics (1996), pp. 55 and 79–80).

Nonetheless, the theoretical and empirical results presented here suggest that the use of a relatively short interval of data for estimating correlations and volatilities may be dangerous. If the interval is typically stable, then not only may the estimated volatilities be too low, depending on whether the assumed level of exponential decay captures the autocorrelation in volatility correctly, but, perhaps more importantly, the estimated correlations between returns will be lower than average. As a result, assessments of market risk may overstate the amount of diversification in a portfolio, leading the investing firm to take on excessive risk. Conversely, if the interval of data employed is a relatively volatile one, then the resulting estimates of correlations will be atypically high, and could lead the firm to take positions that are excessively risk-averse.

Another way in which the link between in-sample volatility and correlation could cause problems for risk managers is in the calculation of worst case scenarios and in stress testing. Put simply, risk managers should not consider the possible effects of a period of high volatility without also taking into account the likely effect that elevated volatility would have on the correlations between asset returns (see Ronn (1995), for a related discussion). Instead, risk managers may need to include information from historical periods of high volatility to form estimates of correlations conditional on the heightened volatility.[21] These conditional correlations could then be used to evaluate the likely distribution of returns under a high volatility scenario. Put differently, the method used for stress testing a model must not (inadvertently) exclude the feature that periods of high volatility will also be periods of elevated correlations.

Supervisors of financial institutions also need to be aware of the link between volatilities and correlations when assessing firms' risk management. For example, under Federal Reserve regulations, an institution applying the market risk capital rules must hold capital based on its internal model's estimates of VaR. The internal model must be based on a minimum observation period of one year, and must be subjected to stress tests appropriate to the institution's particular situation. The VaR calculation should be based on a 99% (one-tailed) confidence level of estimated maximum loss (Federal Reserve (1999), pp. 11–2). In evaluating such internal models, supervisors need to keep in mind the difficulties noted earlier with relying on a relatively short interval of data for information on correlations and the need to form appropriate conditional correlations for stress tests.

Finally, monetary policymakers may also need to be aware of the link between volatility and correlations. Most obviously, correlation breakdowns during periods of financial market turbulence could lead policymakers to reassess the stance of policy in light of the apparent shift in correlations. So long as in-sample changes in correlations only reflect the movements in volatility, however, such reassessment would not be warranted unless private agents' adjustments to the volatility made a change in the stance of monetary policy desirable.

Perhaps more importantly, changes in the stance of monetary policy, particularly if they follow an extended period during which policy has remained unchanged, have the potential to cause volatility in financial markets to increase. Since such an increase in volatility is likely to be associated with

---

[20] Similarly, if the assets under consideration are firm-specific (rather than indexes), the behavior of firms can change over time as managers or business strategies are changed, making older information less useful.

[21] Alternatively, firms might want to use actual data from earlier periods of high volatility to stress test their portfolios. Chase Manhattan indicates that they use asset price movements during the bond market sell-off in 1994, the 1994 Mexican peso crisis and the 1997 Asian markets crisis, as well as internally developed scenarios, when assessing the risk of their portfolio (Chase Manhattan (1999), p. 37).

increases in correlations between asset returns, a change in policy could impose substantial unanticipated risks on market participants if – as discussed earlier – their risk management were based on movements in asset prices during the previous period of relative stability. The resulting adjustments of portfolios by the affected firms could generate outsize effects of policy on asset prices.[22] These relatively large effects may lead policymakers to move more gradually than they otherwise would in such situations, providing a possible explanation for the interest rate smoothing behavior noted by Sack and Wieland (forthcoming). Moreover, uncertainties about the size and timing of such portfolio adjustments would make the likely effects of policy more difficult than usual to assess. This uncertainty would also suggest that a gradual approach would be desirable (Brainard (1967)).[23]

Indeed, the Federal Reserve found that its tightening of monetary policy in 1994, which followed a substantial period of unchanged policy, led market participants to trim their risk profiles. It noted that uncertainty about the policy outlook, as well as "the capital losses following the tightenings, encouraged investors to shorten the maturity of their investments and reduce their degree of leverage" (Federal Reserve (1995), pp. 21–2). While this reaction may only have reflected the revision of overly optimistic beliefs about monetary policy and market volatility, it is also what one would expect to happen if the increase in volatility by itself caused correlations between asset returns to increase. There is some evidence that this was the case; for example, Bankers Trust indicated in its 1994 annual report that movements in interest rates in early 1994 (and also at the end of 1994, when the Mexican peso devaluation occurred) were "unusual in the degree to which interest rates across international markets moved together" (Bankers Trust (1995), p. 23).[24] It went on to note that "this phenomenon of increased correlation among interest rates reduced the risk management benefits derived from diversification across interest-sensitive instruments" (Bankers Trust (1995), p. 23). The bank responded to this unexpected situation by withdrawing from substantial market positions (Bankers Trust (1995), p. 24).

In fact, the possibility that a change in monetary policy could affect market volatility and correlations, and thereby influence the desired risk profiles of market participants, may have been taken into account by the Federal Reserve. In its discussion of the 1994 tightening, the February 1995 Humphrey-Hawkins report noted that:

"The FOMC, at its meeting in early February 1994, agreed that policy should be moved to a less stimulative stance. The pace at which the adjustment to policy should be made was less clear: A rapid shift in policy stance would minimise the risk of allowing inflation pressures to build, while a more gradual move would allow financial markets time to adjust to the changed environment. Although many market participants seemed to anticipate a firming move fairly soon … some investors would undoubtedly reconsider their portfolio strategies." (Federal Reserve (1995), p. 21).

Taking account of these factors, the FOMC agreed to move slowly at first. As a result, the first three policy moves were relatively small (25 basis points), and spread over three months. However, the Federal Reserve also reported that "once market participants seemed to have made substantial adjustments to the new direction of policy, a larger tightening move [of 50 basis points] was implemented in May" (Federal Reserve (1995), p. 21).

---

[22] This mechanism could provide an alternative explanation for the larger effects on asset prices of monetary policy moves that represent a change in the direction of policy, noted by Goodfriend (1991).

[23] In addition, these effects could be reduced by increased transparency about the outlook for policy in advance of a policy move.

[24] The effect of increased volatility on conditional correlations is, of course, only one possible reason for the increase in correlations of asset returns at this time. For example, a structural model of asset returns might suggest that changes in monetary policy should generate relatively highly correlated movements in many asset prices.

Bibliography

Bank for International Settlements, Committee on the Global Financial System (1999): *A Review of Financial Market Events in Autumn 1998.* Basel, October.

Bankers Trust (1994): *Annual Report 1994*. New York.

Bookstaber, Richard (1997): "Global Risk Management: Are We Missing the Point?" *Journal of Portfolio Management*, pp. 102–7.

Boyer, Brian H, Michael S Gibson and Mico Loretan (1999): "Pitfalls in Tests for Changes in Correlations". Federal Reserve Board, *IFS Discussion Paper*, No. 597R, March.

Brainard, William (1967): "Uncertainty and the Effectiveness of Policy". *American Economic Review, Papers and Proceedings*, Vol. 57, pp. 411–25.

Chase Manhattan Corp. (1999): *Annual Report 1998*. New York.

Drazen, Alan (1998): "Political Contagion in Currency Crises". *Mimeo*, University of Maryland.

Eichengreen, Barry, Andrew Rose and C Wyplosz (1996): "Contagious Currency Crises". *NBER Working Paper*, No. 5681.

Forbes, Kristin and Roberto Rigobon (1999): "No Contagion, Only Interdependence: Measuring stock market co-movements". *NBER Working Paper*, No. 7267, July.

Federal Reserve Board (1995): *Monetary Policy Report to the Congress Pursuant to the Full Employment and Balanced Growth Act of 1978.* February 21.

Federal Reserve Board (1999): *Trading and Capital Markets Activities Manual: Capital Adequacy*. Washington, D.C.

Gerlach, Stefan and Frank Smets (1995): "Contagious Speculative Attacks". *European Journal of Political Economy*.

Goldberger, Arthur S (1991): *A Course in Econometrics*. Cambridge, MA: Harvard University Press.

Goodfriend, Marvin (1991): "Interest Rates and the Conduct of Monetary Policy". *Carnegie-Rochester Conference Series on Public Policy*, Vol. 34, pp. 7–30.

JP Morgan and Co. (1999): *Annual Report 1998*. New York.

Jansen, D W and C G de Vries (1991): "On the Frequency of Large Stock Returns: Putting Booms and Busts into Perspective". *Review of Economics and Statistics*, Vol. 73, pp. 18–24.

Kodres, Laura E and Matthew Pritsker (1999): "A Rational Expectations Model of Financial Contagion". *Mimeo*, Federal Reserve Board.

Longin, François and Bruno Solnik (1998): "Correlation Structure of International Equity Markets During Extremely Volatile Periods". *Mimeo*, Group HEC.

Loretan, Mico and Peter C B Phillips (1994): "Testing the Covariance Stationarity of Heavy-Tailed Time Series". *Journal of Empirical Finance*, Vol. 1, pp. 211–48.

Mandelbrot, B B (1963): "The Variation of Certain Speculative Prices". *Journal of Business*, Vol. 36, pp. 394–419.

RiskMetrics (1996): *RiskMetrics–Technical Document.* 4th ed. New York: JP Morgan/Reuters.

Ronn, Ehud I (1995): "The Impact of Large Changes in Asset Prices on Intra-Market Correlations in the Stock and Bond Markets". *Mimeo*, Department of Finance, University of Texas at Austin.

Sack, Brian and Volker Wieland: "Interest-Rate Smoothing and Optimal Monetary Policy: A Review of Recent Empirical Evidence". *Journal of Economics and Business* (forthcoming).

Silverman, B W (1986): *Density Estimation for Statistics and Data Analysis*. London: Chapman and Hall.

Spanos, Aris (1986): *Statistical Foundations of Econometric Modelling*. Cambridge: Cambridge University Press.

Asset price crises and banking crises: some empirical evidence

Anne Vila[1]

1. Introduction

The aim of this paper is to see whether, for a range of countries and time periods, there is any systematic relationship between stock market collapses and banking system crises. This is intended to be a first step in a larger study, one which aims ultimately to see whether asset price movements have any implications for the stability of the banking system in developed countries. The present paper, however, largely confines itself to an atheoretical examination of the data, so as to explore what there is to be explained. Three decades of equity and banking data, drawn from 14 countries, are examined.

Three questions in particular are put to these data. First, is there any evidence of association between stock market crashes and banking crises? Second, insofar as there is any association, does the depth or the length of stock market falls affect the severity of banking sector problems? Third, have the size and frequency of either stock market crashes or banking crises shown any sign of varying over time?

With this paper, we hope to contribute to the debate on the role of central banks with respect to asset price volatility. While it is generally acknowledged that central banks should focus in the first instance on price stability in product markets, there is now a growing acceptance that they should at least monitor price developments in asset markets.[2] One reason for doing so is that asset prices can affect aggregate demand directly or via the balance sheet channel (i.e. through their effects on household and business balance sheets). A second reason is that overvaluation in asset markets could lead to financial fragility. In particular, there is widespread concern that the growth of asset price bubbles and their subsequent bursting could create systemic risk. A third reason for central banks to be concerned about asset price volatility is that this may be a manifestation of poorly implemented financial reforms that lead to excessive lending and risk-taking, and to asset price booms and subsequent collapses.[3]

Financial institutions in particular are vulnerable to asset price collapses, because of the decline in the value of collateral they hold, and also because of the general increase in uncertainty that may lead to a flight to quality and to a widespread reduction in lending that could affect even solvent financial institutions.[4] If asset price collapses were to lead to bank failures, further financial stability problems could arise as a result of contagion. This in turn could lead to business failures, unemployment and a fully fledged economic downturn. Moreover, the costs associated with banking crises are high, both in terms of declines in real output and in terms of transfers from the public to distressed banks and their creditors (Kaufman (1999)). For example, recent research by the IMF (1998) into the occurrence of banking crises estimates that the cumulative actual and potential losses in output associated with 54 banking crises across developed and emerging markets (pre-dating the Asia crisis) averaged 11.6% of GDP.

---

[1] Financial Intermediaries Division, Bank of England. Comments from Phil Davis, Ian Michael, Paul Tucker, Geoffrey Wood and from participants of a Bank of England financial stability workshop and from the BIS autumn meeting of central bank ecomonists greatly improved the present paper. I also thank Faysal Maruf for his outstanding research assistance. The views expressed in this paper are mine and not necessarily those of the Bank of England. Any errors and omissions are of course my own.

[2] See, for example, Greenspan (1999), Vickers (1999), Bernanke and Gertler (1999) and Gertler et al. (1998).

[3] See, for example, Borio et al. (1994) and Schinasi and Hargraves (1993).

[4] See, for example, Kaufman (1998).

Recently, significant progress has been made towards studying the relationship between banking and currency crises in a more systematic way.[5] In contrast, the study of the relationship between banking and equity crises is largely limited to case studies. Hence, we do not know whether banking crises systematically precede or follow equity market crises. Likewise, we do not know how severe a crisis has to be in order to spill over into other parts of the financial sector. As a result, we remain quite uncertain when asked to define the financial stability consequences of a sharp fall in equity valuations.

The main results of this paper can be summarised as follows. First, we do not find any evidence of a systematic association between equity market crises and banking crises within countries. In particular, we cannot establish that equity price collapses necessarily lead to banking crises. Second, we find that if there is an association, the length or severity of the equity price decline is irrelevant. Third, we find that both equity market and banking crises have become less severe over time: crises in the 1970s were on average longer and led, in the case of the former, to bigger price falls than in the following decades. Fourth, we cannot establish that periods of large stock market increases are more likely to lead to simultaneous crises in either the equity market or the banking sector.

When looking at the effect of banking crises on the equity market, we observe mixed evidence of banking crises leading to large equity price falls. But we cannot conclude that banking crises systematically cause large-scale liquidations of equity. Finally, we find weak evidence of increased bank lending prior to equity market crises.

The paper further illustrates the difficulty of accurately measuring banking crises. Qualitative measures used in the currency crisis literature are not without flaws, yet alternative measures proposed in the present paper turn out to be inconsistent with existing measures in several instances. This in turn affects the observed relationship between banking and equity market crises.

The remainder of the paper is organised as follows. In Section 2, we review the recent literature on the relationship between asset market crises and banking crises. Then in Section 3, the data are outlined, and the method by which equity market crises and banking crises can be identified are set out. In Section 4, we present our main results regarding the relationships between equity price and banking crises. Section 5 concludes.

2. Literature review

2.1 Theoretical models of banking crises and asset price crises

The views expressed in the literature on banking crises fall broadly into two groups. The first view is that banking crises are random events, unrelated to changes in the real economy. Banking crises can arise from self-fulfilling expectations, as modelled by Diamond and Dybvig (1983), among others. In their model, two possible equilibria can emerge. In the first equilibrium, a depositor may believe that a banking crisis is about to occur and that all other depositors will try to obtain liquid funds. As a result, his optimal strategy is to withdraw his own liquid assets immediately. A speculative attack follows and banks run out of liquid funds. An alternative equilibrium is one in which no one believes that a bank run will occur and banks have sufficient funds to meet true liquidity demands, such that no crisis develops. Unfortunately, while conceptually quite plausible, these multiple equilibrium models have received weak support from historical data (see e.g. Gorton (1988)).

The second view is that banking crises are related to the real business cycle and are triggered by sudden changes in aggregate risk.[6] As an economic downturn is likely to reduce the value of a bank's assets, signals about an impending downturn may induce depositors to consider withdrawing their funds. For example, Kaufman (1998) argues that banks fail through exposure to the same common shock (e.g. downturns in the economy or in the stock and real estate markets) rather than through

[5] See, for example, Kaminsky et al. (1998) and Berg and Pattillo (1999).

[6] See Allen and Gale (1998a) for a review of business cycle papers.

exposure to other bank failures that were the result of idiosyncratic factors. Relying on historical case studies rather than a formal model, he concludes that "to the extent contagion exists in the banking sector, at least in the United States, it appears to be rational and information based ignited by a common shock."

Recent papers combine the speculative attack view and the business cycle view. Chari and Jagannathan (1988) consider a model where informed agents observe a negative signal about the performance of a risky investment. Uninformed agents, however, are unclear about the motivation for these withdrawals (i.e. whether they are information-based or not) and may make decisions similar to the ones described in Diamond and Dybvig (1983). Hence, bank runs can occur either because the fundamentals look bad or because investors believe liquidity demands to be excessive.

Common to all papers is the insight that asymmetric information is a key factor in triggering a banking crisis. At the same time, asymmetric information problems (both adverse selection and moral hazard) are generally intensified during periods of sharp asset price falls, as lenders' collateral values and borrowing firms' net worth decline. This in turn increases the possibility of a banking crisis. Mishkin (1994) argues that a large number of US financial crises that occurred in the 19th and early 20th centuries can be explained using this asymmetric information framework, and that they typically started with stock market crashes.

In a series of theoretical papers, Allen and Gale formally relate asset price declines and banking crises. In Allen and Gale (1998b), they model a representative bank which holds illiquid assets with risky returns. A bank run will occur if depositors expect low returns on the risky asset. The crisis will spill over into asset markets if banks attempt to sell their risky assets in order to meet depositors' demands for liquidity. In a related model, Allen and Gale (1999) consider banks with cross-holdings of deposits. In this model, contagion and eventually bankruptcies occur when banks liquidate their claims on other banks in order to meet liquidity demands from their customers.

Marshall (1998) argues that asset price declines may lead to banking crises if investors believe stock prices to be a function of the probability of future crises. As in Diamond and Dybvig (1983), Marshall considers a model with two equilibria, with the "bad one" leading to a self-fulfilling liquidity crisis in the banking sector. Contagion arises when defaults are viewed as a signal that the economy is about to shift to the bad equilibrium. Of course, a single default could be a firm-specific event and should not necessarily lead to a reduction in capital provision by investors. Yet, when investors are imperfectly informed, they may erroneously attribute the default of a single firm to a widespread reduction in investor confidence. This mechanism could in turn lead to a (further) decline in equity prices.

The above models show how problems in the banking sector can affect asset prices or how signals about lower future asset returns may cause bank runs. But the banking crisis literature does not incorporate the possibility of a bubble in asset prices, nor does it model the mechanism by which the bursting of the bubble would lead to a full-blown liquidity crisis. This is clearly a gap in the theoretical literature. Allen and Gale (1998a) go some way towards modelling this issue, by linking sudden changes in credit availability and asset price movements. In their model, investors build their expectations about future credit supply into their decisions about how much to borrow from a representative bank and how much to pay for a risky asset. An agency problem exists because investors can default on their debt when asset returns are low, but keep the surplus when returns are high. A bubble develops when investors are willing to bid up the price of the risky asset above the price they would be willing to pay if they were not able to shift the risk as described. If the credit expansion is suddenly less than expected, investors may not be able to repay their loans, and may have to sell their risky assets instead. This may lead to a collapse in asset prices. Allen and Gale (1998a) do not, however, model the generalised collapse of the banking sector described in the multiple equilibrium models mentioned above.

A further criticism is that the banking crisis models are less relevant in countries where the banking sector has relatively low holdings of risky assets, such as equity or property. But, arguably, banks' exposure to corporate or household defaults through their loan books could give rise to qualitatively similar transmission mechanisms. A sharp fall in equity or property prices could also cause banks to liquidate relatively liquid assets such as bonds. In this case, the association between asset price and banking crises could result from a flight to quality or to liquidity.

2.2 Empirical questions raised by the theory

The theoretical papers mentioned in the previous section suggest a number of empirical questions worth examining:

(i) Are bank runs preceded by periods of deteriorating equity returns?

(ii) Do bank runs contribute to a further fall in equity prices (as banks attempt to sell their assets in order to meet the sudden liquidity demands)?

(iii) Are equity price bubbles associated with rapidly expanding credit provision by banks (which in the long run could make the latter more vulnerable to default risk)?

The literature is unclear, however, on the exact timing of these events, or on the severity of the fall in equity prices required for a bank run to occur. The literature also does not provide any empirical predictions regarding the impact of equity price bubbles (both their growth and their subsequent bursting) on the banking sector. Based on these observations, we put the following questions to the data:

(Q1) Are banking crises preceded by equity price crises, or are equity price crises preceded by banking crises?

(Q2) Insofar as there is any association, does the nature of the equity price crisis (length, intensity) matter?

(Q3) Do equity prices decline during a banking crisis?

(Q4) Has the size or frequency of either equity crises or banking crises shown any sign of varying over time?

(Q5) Are equity market crises preceded by periods of unusually large equity price increases (possible evidence of asset price bubbles)?

(Q6) Is there evidence of an increase in bank lending prior to equity price crises (possible evidence of asset price bubbles)?

3. Data and methodology

3.1 Identifying equity market crises

We use a data set of monthly price data for Morgan Stanley Capital International (MSCI) stock indices of 14 developed countries.[7] For most countries, they span the period January 1970 to July 1999. To identify equity crises, we closely follow the methodology of Patel and Sarkar (1998). First, we will work with the ratio CMAX, defined as follows:

$CMAX_t$ = index level at time t/maximum index over the past 24 months.

The advantage of using this measure is that sharp price declines are more visible, and as such easier to date, than if we were to work with the raw index data. The rolling maximum in the denominator was defined over a relatively short period (24 months) to avoid losing too many data points. We experimented with periods of up to five years. While the resulting series looks smoother, the identification of the key dates ((i) to (iv) below) was unaffected.

[7] We also collected data for 14 emerging markets that we plan to examine in future research.

Also following Patel and Sarkar (1998), we define the following concepts:

(i) The beginning of the crisis: this is the month in which the CMAX reaches its (local) maximum prior to the month in which the crash (defined in (ii) below) was triggered.

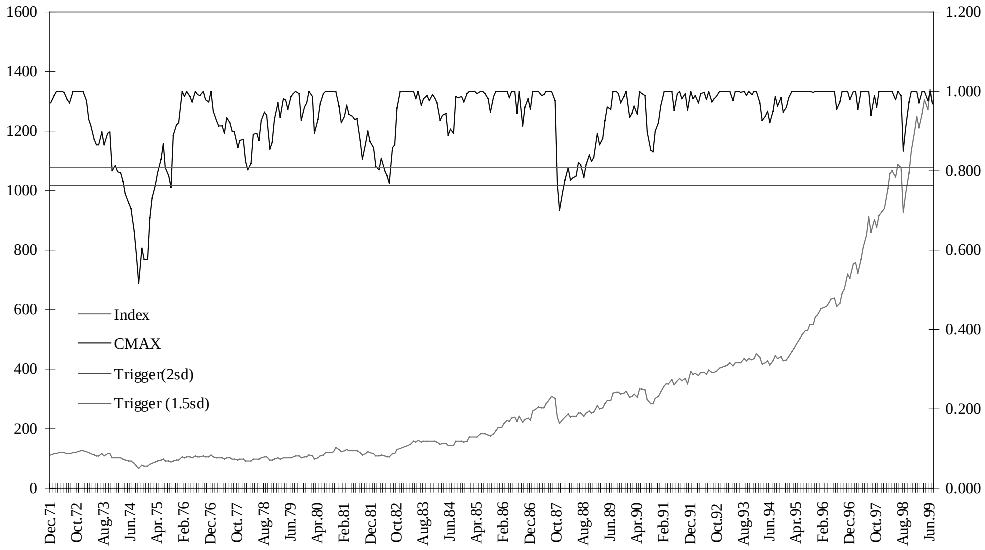
(ii) The beginning of the crash: this is the month in which the CMAX falls below a trigger level, defined below.

(iii) The trough: this is the month in which the CMAX reaches its minimum during the crisis.

(iv) The recovery: this is the month in which the CMAX reaches its pre-crash maximum.

We used two trigger points, defined as 1.5 and 2 standard deviations below the mean of the CMAX series. We further calculate the length of the crisis, measured from the beginning of the crisis to the end, and the magnitude of the price decline between the beginning of the crisis and the trough.

Figure 1
US equity market index



Source: Datastream.

An example of these definitions is given below, where we calculated CMAX for the US market. Using the 2 standard deviation trigger, we identify two crisis periods, from December 1972 to January 1976 and from August 1987 to July 1989. Crashes occurred in April 1974 and November 1987 (see Figure 1).[8] The crises lasted 36 and 22 months, respectively, and the respective price declines were 48% and 30%. A 1.5 standard deviation crisis is registered in the early 1980s, from November 1980 to November 1982. In this instance, the market crashed in September 1981 and prices fell by 23%. This crisis lasted for 23 months. Using the CMAX method and a trigger of 2 standard deviations, we identified a total of 28 equity market crises. When using the 1.5 standard deviation trigger, we identified a further 10 crises. The full list of equity crises is reproduced in Appendix A.

3.2 Identifying banking crises

In contrast to equity crises, banking crises are more difficult to measure precisely. This follows from the difficulty in capturing the complexity of a crisis with a single variable and from a lack of suitable data.[9] In this section, we first consider the measures that have been used in the fast growing empirical

---

8 Recall that we are using monthly returns (based on beginning-of-month prices) to construct the CMAX series. So the market fall of 19–20 October 1987 will show up in the November 1987 return.

9 Davis (1999) discusses the difficulty of measuring financial instability in general.

literature on the determinants of banking and currency crises. It should be noted that this literature is primarily concerned with assessing the probability of a crisis. As such, its objective is to develop a set of indicators that could predict a banking or currency crisis, and less time is devoted to defining the crisis itself. For example, a number of studies define the onset of a banking crisis by the first official intervention, even though the banking sector may have become increasingly fragile in the preceding months or years.[10] In addition to these qualitative measures, we propose two alternative indicators, one based on bank equity prices and one based on aggregate bank balance sheet data.

The banking and currency crisis literature starting with Kaminsky and Reinhart (1999) typically employs a combination of events to define the beginning of a banking crisis. These may include: i) bank runs that lead to a closure, merger or takeover by the public sector of one or more financial institutions; and ii) in the absence of runs, the closure, merger, takeover or large-scale government assistance of an important financial institution that marks the beginning of a string of similar outcomes for similar institutions. More recent papers combine this qualitative approach with a limited number of quantitative criteria. Examples are Lindgren et al (1996), Demirgüç-Kunt and Detragiache (1998a) and (1998b), and Glick and Hutchinson (1999). They define a banking crisis as a situation where at least one of the following conditions holds: i) the ratio of non-performing assets to total assets is greater than 2% of GDP; ii) the cost of the rescue operation is at least 2% of GDP; iii) banking sector problems result in large-scale nationalisation of banks; and iv) extensive bank runs lead to emergency measures.

In this paper, we use the Glick and Hutchinson list as it is more selective than those produced by earlier studies.[11] A drawback is that they limit themselves to reporting annual data. In their view, it is not possible to date banking crises with more precision. For our sample, the Glick and Hutchinson method produces 13 banking crises, listed in Appendix B. Unfortunately, the qualitative methods do not always distinguish between problems encountered by single banks that have no systemic implications and banking crises that involve several banks of systemic importance. From Appendix B it can be seen that Glick and Hutchinson correctly identify the banking crises in the Nordic countries in the early 1990s, but fail elsewhere. For example, the 1984 UK banking crisis reported by them reflects the failure of an individual bank rather than a systemic banking crisis.[12]

An alternative way of defining a banking crisis is to use aggregate balance sheet data. If a banking crisis were the result of bank runs, namely the simultaneous withdrawal of deposits from one or more banks, then one could interpret a sharp fall in aggregate bank deposits as the beginning of a banking crisis. But Glick and Hutchinson (1999) point out that in recent years most banking problems in developed countries have not been associated with bank runs, but rather with problems on the asset side of the balance sheet. Moreover, a bank run (or a large-scale government intervention to prevent a potential bank run) is likely to have been preceded by a period of deterioration in the quality of a bank's assets. This is confirmed by Hardy and Pazarbasioglu (1998), who find that bank deposits in their large sample of banking crises in both developed and emerging markets start falling in real terms before a banking crisis is fully acknowledged, and continue to fall during the crisis. Another problem with using deposits is that changes in aggregate deposit growth may reflect macroeconomic factors rather than critical problems in the banking sector.

The banking and currency crisis literature frequently uses two other measures to identify bank balance sheet problems: the stock of non-performing loans as a percentage of total assets and bank lending as a percentage of GDP. With respect to the latter, it is assumed that if bank lending expands rapidly in a relatively short period of time, banks' screening is likely to be imperfect. This in turn may lead to a relatively high proportion of non-performing loans in the future (see, for example, Sachs et al. (1996)). Hardy and Pazarbasioglu (1998) report a boom and bust pattern in bank lending to the private sector

---

[10] See, for example, Kaminsky and Reinhart (1999) and Hardy and Pazarbasioglu (1998).

[11] For banking distress to be included in their study, it has to be mentioned in both Lindgren et al. (1996) and Demirgüç-Kunt and Detragiache (1998a).

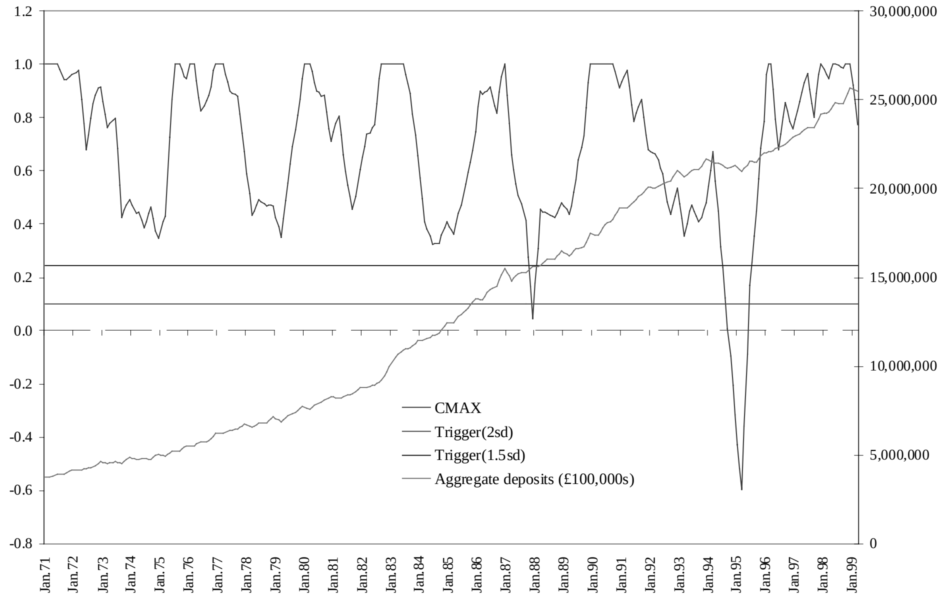
[12] See, for example, Davis (1995).

prior to banking crises, with a further decline during the crisis. Some authors also suggest looking at increased bankruptcies as signals of an impending banking crisis. Unfortunately, for many countries, such data are often available only at low frequencies or not available at all.

Keeping in mind these conceptual limitations, we collected data on aggregate bank deposits and aggregate bank lending. All data were taken from the International Financial Statistics (IFS) database. Bank deposits are the sum of demand deposits (line 24) and time, savings and foreign currency deposits (line 25). Aggregate bank lending is measured by claims on the private sector by deposit money banks (line 22d). The remaining variables discussed above (non-performing loans or bankruptcies) were not available in the IFS database. Monthly data were available for both deposit and lending series, but in many instances the data spanned a shorter sample period than the equity price data. For all variables, we first computed the percentage change in the level of the variable compared to a year earlier. This procedure ensures stationarity in the data and removes possible seasonal effects.

To identify the start of a banking crisis, we examine the aggregate deposit growth series.[13] By analogy with the equity price data, we employ the CMAX method to identify "unusual" movements in aggregate deposit growth, and we define the trigger level to be either 1.5 or 2 standard deviations below the mean of the series. To illustrate this crisis measure, we look again at the US case. Figure 2 shows two periods with very large changes in deposit growth, from December 1986 to December 1989 and from September 1990 to February 1996. During each crisis, the series fell through the 2 standard deviation trigger, in November 1987 and July 1984, respectively. The crises lasted 36 and 65 months, respectively. In each case, deposit growth fell by about 11% from the beginning of the crisis to the trough.

Figure 2
US aggregate bank deposits



Source: Datastream.

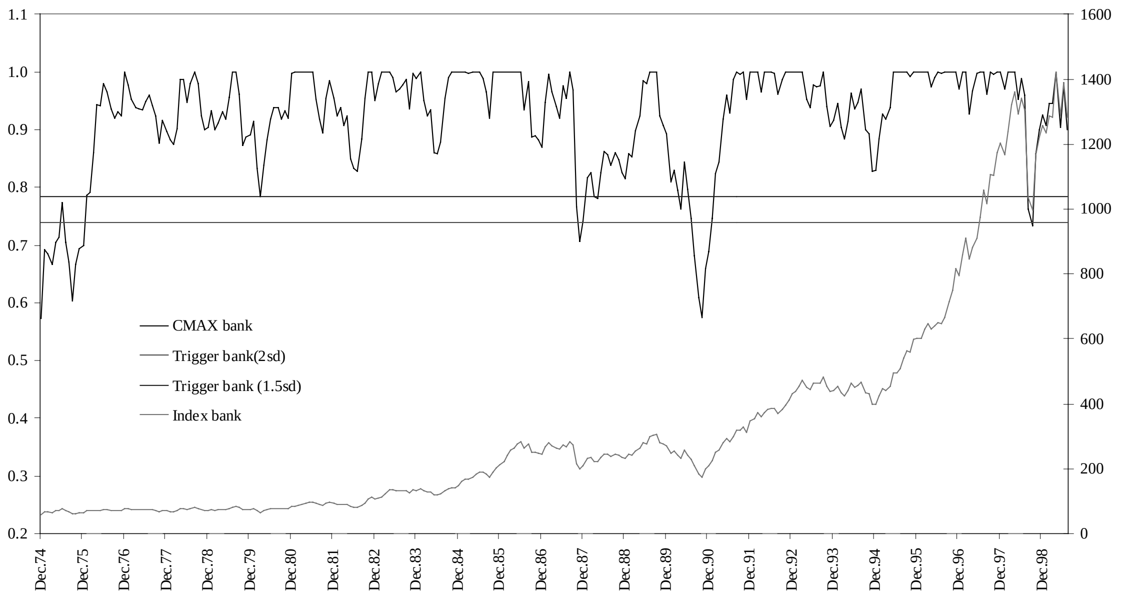
In total, this method identified 24 banking crises when using the 2 standard deviation trigger, and 39 crises when using the 1.5 standard deviation trigger. The full list of crises is presented in Appendix C. Note that the overlap with the qualitative indicators is weak, highlighting the problems with defining banking crises described above. For example, it is likely that the observed falls in aggregate deposit growth of several countries in the early 1990s reflect tightening monetary conditions and the onset of the recession in the relevant economies, rather than crises in their banking sectors.

[13] The CMAX method is less suitable for the lending variable, as this variable is reported to first rise and then decline prior to a banking crisis (see, for example, Hardy and Pazarbasioglu (1998)).

Another indicator of banking problems and/or crises is bank equity. Falling equity prices could be seen as an indication of the increased perceived riskiness of individual banks or the banking sector as a whole. One advantage of using bank equity is that the beginning and end of the banking crisis can easily be defined. Unfortunately, in many countries banks are not traded publicly, or banking indices have only been constructed fairly recently. Probably for this reason, the banking and currency crisis literature tends not to use this measure. A further complication that arises when using bank equity price data is that one needs to distinguish between general market movements and idiosyncratic movements that are the result of rising required rates of return for the banking sector only.[14]

We calculated the CMAX measure (together with relevant trigger points) for a country's banking sector index, where available (again using MSCI indices). Figure 3 shows these measures for the United States. Using either the 1.5 or 2 standard deviation triggers, we identify three crisis periods for the banking sector, from August 1987 to July 1989, from September 1989 to August 1991 and from April 1998 to April 1999.[15] These crises lasted 23, 23 and 12 months, respectively, and caused declines in the banking index of 29%, 42% and 26%.

Figure 3
US bank equity index



Source: Datastream.

The CMAX results for the entire sample are summarised in Appendix D. Using the 1.5 standard deviation trigger, we identify 38 banking crises. It should be noted, however, that in many cases our data start much later than for the equity indices. This data limitation is likely to lead us to underestimate the frequency of associated banking and asset price crises. A second problem is that, as noted earlier, a number of crisis periods reflect general market declines rather than banking sector crises, which will lead us to overestimate the frequency of association. This measurement problem may also explain the lack of consistency across our three banking crisis measures that are apparent from Appendices B–D.

---

[14] Clare and Priestley (1999) do so in their study of nine Norwegian banks: they use bank equity prices to estimate a CAPM model with time-varying volatility and obtain market-based estimates of the probability of failure.

[15] Unfortunately, most banking price series start after 1973, so in many instances the results in Appendix D do not contain the 1973/4 equity market crisis, to give but one example.

4. Equity price crises and banking crises: empirical results

In this section, we present the empirical results for hypotheses (Q1) to (Q6) as identified in Section 2. Unless otherwise specified, we employ the broadest definition of a crisis (i.e. based on the 1.5 standard deviation trigger). To identify twin asset price and banking crises, it is useful to examine the following matrix, adapted from the banking and currency crisis literature.

	Asset price crisis at t	No asset price crisis at t
Bank crisis at t	$A_{t,\,t}$	$B_{t,\,t}$
No bank crisis at t	$C_{t,\,t}$	$D_{t,\,t}$

For example, we can use this matrix to learn in how many instances an asset price crisis occurring during period t was accompanied by a banking crisis in period t ($A_{t,\,t}$), or not accompanied by a banking crisis ($C_{t,\,t}$). A similar matrix could be constructed to tabulate the number of instances in which an asset price crisis in period t was preceded or followed by a banking crisis in period t–1 or t+1, respectively. In what follows, we look for within-country associations only, but a similar matrix could be constructed to identify associations across countries.

Table 1 sheds light on the first question, using all three criteria to define a banking crisis. In each case, the table presents the number of twin banking and equity market crises, defined as episodes where the *onset* of an equity market crisis is either followed *or* preceded by the onset of a banking crisis within 12 months. We also looked at instances where the banking crisis began within a 24-month period surrounding the start of the stock market crisis. Unless otherwise specified, our discussion focuses on the former window.

Table 1
Measuring the association between banking and equity price crises (Q1)

	12-month window Number[1]	24-month window Number[1]
Total number of equity crises	38	
Panel I: Using bank equity		
Total number of banking crises	38	38
Asset price crises associated with banking crisis[2]	16	18
Asset price crises not associated with banking crisis	6	4
Banking crises associated with asset price crisis[3]	17	19
Banking crises not associated with asset price crisis	21	19
Panel II: Using qualitative data		
Total number of banking crises	13	13
Asset price crises associated with banking crisis[2]	4	5
Asset price crises not associated with banking crisis	34	33
Banking crises associated with asset price crisis[3]	4	5
Banking crises not associated with asset price crisis	8	6
Panel III: Using balance sheet data		
Total number of banking crises	39	
Asset price crises associated with banking crisis[2]	9	11
Asset price crises not associated with banking crisis	27	25
Banking crises associated with asset price crisis[3]	9	11
Banking crises not associated with asset price crisis	29	28

[1] When comparing isolated and twin crises, two numbers may not add up because of the later start of many bank data. [2] Frequency with which asset price crisis at t is accompanied by banking crisis in either $t+k$ or $t–k$, where k = 12 or 24 months. [3] Frequency with which banking crisis at t is accompanied by asset price crisis in either $t+k$ or $t–k$, where k = 12 or 24 months.

When using bank equity as our criterion, we find that 16 out of 38 equity market crises could be associated with a banking crisis ($A_{t,\,t}$), while six other equity crises were isolated occurrences ($C_{t,\,t}$).[16] Twin crises occurred in Hong Kong and Sweden in the 1990s, Australia, Canada, Denmark, Italy, Japan, Spain, the United Kingdom and the United States in the 1980s and the United Kingdom in the 1970s. When looking at banking crises first, we find similar numbers of banking crises associated with equity price crises ($A_{t,\,t}$: 17), but a larger number of banking crises which neither resulted in nor were preceded by equity crises ($B_{t,\,t}$: 21).

The association becomes even weaker when using the qualitative criteria, as can be seen from panel II. The Glick and Hutchinson criterion returned four twin crises (Norway, Sweden, the United Kingdom and the United States). Recall, however, that the latter method employed years rather than months to date the banking crisis. In any case, the disparity between the results from this and the previous method suggest that a fair amount of measurement error is present.

Panel III repeats the exercise, this time using the balance sheet method to identify banking crises. This time, we find that nine out of 38 equity price crises were associated with banking crises ($A_{t,\,t}$). They occurred in Australia in the 1970s, Japan, Norway, Sweden and the United States in the 1980s and Denmark, Finland, Germany and Sweden in the 1990s. This number goes up to 11 when we consider a 24-month window either way (Canada and Spain). When looking at banking crises first, we find that out of the 36 banking crises identified by the balance sheet method, nine are in fact twin crises ($A_{t,\,t}$), with the remaining 29 being banking crises that were neither preceded nor followed by asset price crises ($B_{t,\,t}$).

To conclude, Table 1 shows that irrespective of our methodology, the association between equity and banking crises is weak. In particular, the empirical evidence is too weak to provide support for the view that stock price declines always lead to banking crises.

Table 2 looks at the nature of equity price crises, namely their length (number of months) and the total price decline that occurred in the equity market. We are interested in learning whether or not twin crises are systematically preceded by more severe equity price crises. For the total sample, the average equity crisis lasted 38 months and prices fell by 43% on average. Crises varied both in their length and their intensity, however, with the longest crisis lasting 82 months (Spain, April 1974 – March 1981), and the most severe crisis entailing an 89% price decline (Hong Kong, 1973).

Table 2
Does the nature of the equity crisis affect the likelihood of twin crises (Q2)?

	12-month window		24-month window	
	Length of equity crisis (months)	Price decline (%)	Length of equity crisis (months)	Price decline (%)
All equity crises	37	–42.9		
Panel I: Using bank equity				
Equity crises associated with banking crisis	35	–39.5	36	–39.1
Equity crises not associated with banking crisis	33	–32.2	28	–33
Panel II: Using qualitative data				
Equity crises associated with banking crisis	22	–33.2	24	–29.6
Equity crises not associated with banking crisis	38	–44	36	–42.03
Panel III: Using balance sheet data				
Equity crises associated with banking crisis	33	–40.65	34	–40.66
Equity crises not associated with banking crisis	38	–41.27	38	–41.32

[16] For the remaining 16 asset price crisis episodes, no bank equity data were available.

When using bank equity data to identify banking crises, we see that equity crises associated with banking crises tend to last longer than those not associated with banking crises, and to result in larger price declines. But when using qualitative or balance sheet data to identify banking crises, we obtain the opposite result: equity price crises not associated with banking crises last longer and witness larger price declines. Hence, we cannot conclude that the more severe the equity price crisis, the more likely a banking crisis is to follow. Arguably, the results in this section are affected by the small number of twin crises that were identified in the first place.

Table 3 looks at the behaviour of equity prices during a banking crisis, both those occurring in isolation and those associated with equity price crises. Large falls in equity prices during an isolated banking crisis might suggest that investors are liquidating their equity holdings because of reduced confidence in the banking sector and/or reduced access to bank credit. Significant equity price falls during a twin crisis could reflect concerns about both overvaluation of the equity market and increased fragility in the banking sector.

Table 3 measures the percentage fall in the overall equity index from the beginning of the banking crisis to the trough. The table provides a very mixed picture. When using the bank equity criterion (panel I), we find that equity returns were indeed negative during banking crises, and even more so during twin crises. But since this method does not make an accurate distinction between general market and bank equity movements, we cannot unambiguously interpret these negative returns as a manifestation of banking sector problems. When using the bank balance sheet method (panel III), we report negative returns during twin crises only. Finally, the qualitative method (panel II) yields positive returns during both isolated and twin crises. It should be noted that since this method does not provide a trough date, the price decline was measured from the beginning of the crisis to the end. The reported positive returns may therefore mask an actual decline during the first phase of the crisis (from the beginning until the trough). Overall, the evidence seems too weak to conclude that banking problems lead to a spillover into asset markets as modelled by, for example, Allen and Gale (1998b).

Table 3

Do equity prices decline further during a banking crisis (Q3)?

	From beginning of crisis to trough	
	12-month window	24-month window
	% decline of equity index	
Panel I: Bank equity		
All banking crises	–26.03	
Banking crises associated with equity crisis	–34.12[1]	–29.00
Banking crises not associated with equity crisis	–16.78	–21.58
Panel II: Qualitative data[2]		
All banking crises	51.17	
Banking crises associated with equity crisis	109.07	117.56[1]
Banking crises not associated with equity crisis	25.44	9.68
Panel III: Bank balance sheet data		
All banking crises	23.12	
Banking crises associated with equity crisis	–4.70[1]	16.32
Banking crises not associated with equity crisis	32.06	26.60
Benchmarks		
Total sample	12.85	
1970s	6.08	
1980s	19.56	
1990s	10.98	

[1] Denotes that results for twin crisis are significantly different from those during other crises (95%). [2] Uses end-date instead.

Table 4 documents the changing nature of both equity and banking crises over time. Panel I shows that stock market crises in the 1970s were on average longer and led to bigger price falls than in the subsequent decades. In contrast, declines in bank equity prices (panel II) were longer and more pronounced in the 1980s, although this result is possibly biased because many of the data series were not available for the 1970s. Finally, panel III shows that when considering bank balance sheet data, banking crises have become shorter and characterised by smaller falls in deposit growth over time.

Table 4
Changing nature of crises (Q4)

	Total period	1970s	1980s	1990s
Panel I: Equity crises				
Number of crises	38	15	18	5
Average length of crisis	37	41	33	36
% decline to trough	–42.89	–49.97	–37.44	–41.29
Panel II: Banking crises using bank equity				
Number of crises	38	4	19	15
Average length of crisis	31	30	34	23*
% decline to trough	–39.84	–35.03	–42.09	–38.15
Panel III: Banking crises using bank balance sheet data				
Number of crises	39	6	12	21
Average length of crisis	40	53	41	37
% change in deposits	8.20	15.42	12.74	3.88
% change in deposit growth (beginning to trough)	–20.32	–34.19	–27.51	–12.91

* Most banking crises of the 1990s have not yet ended, according to this definition.

Table 5 addresses the question of whether equity market crises are preceded by periods of unusually large price increases which could be interpreted as possible evidence of asset price bubbles. The empirical literature on bubbles argues that if bubbles lead to very large price movements, both during the final periods of the bubble growth and after it has burst, the distribution of asset prices will exhibit negative skewness and large kurtosis. Unfortunately, many of the empirical tests in this literature have proved inconclusive, primarily because market fundamentals and bubbles could be characterised by similar statistical properties, and it is now widely acknowledged that asset price bubbles cannot be identified unambiguously. While keeping the shortcomings of these tests in mind, it is still worthwhile to examine the distributional properties of asset price returns before the onset of an equity price crisis, and compare them with benchmarks for "normal" periods.[17]

When considering the entire sample of 38 equity price crises, we see that average returns were higher than historical benchmarks in the three years preceding the start of the crisis, though the differences are not statistically significant. But neither skewness nor kurtosis was particularly high. Skewness measures were positive though, as one would expect in a rising market but, except for the two-year period before the crisis, remained close to zero. The kurtosis did not indicate significant departure from normality and therefore did not point to a preponderance of very large market movements in the period preceding the stock market crisis. Hence, while stock price crises seem to occur after periods of rapid price increases, insufficient evidence is available to designate these as bubble periods.

[17] Assuming normality for equity returns, negative skewness points to the occurrence of a larger number of negative returns than indicated by the symmetric normal distribution (which has zero skewness). The benchmark for our kurtosis measure (i.e. the occurrence of a larger number of very large positive or negative returns than characteristic for a normal distribution) is 0. A negative number indicates that the actual distribution of returns is flatter (has more weight in the tails) than the normal distribution.

Table 5
Are equity crises preceded by large price movements (Q5)?

	Returns before crisis			Skewness before crisis			Kurtosis before crisis		
	1 year	2 years	3 years	1 year	2 years	3 years	1 year	2 years	3 years
All equity crises	31.83	22.40	21.61	0.29	0.44	0.52	–0.21	–0.09	–0.13
Panel I: using bank equity									
12-month window:									
Equity crises associated with banking crisis	37.67	25.73	24.85	0.05	0.62	0.35	0.14	0.08	0.17
Equity crises not associated with banking crisis	15.31	17.45	13.35	0.56	0.29	0.17	–0.28	–0.47	–0.92
24-month window:									
Equity crises associated with banking crisis	34.01	24.45	24.16	0.72	0.43	0.35	0.08	0.04	0.02
Equity crises not associated with banking crisis	28.22	23.19	13.07	–0.03	0.62	0.42	–0.47	–0.68	–0.81
Panel II: Using qualitative data									
12-month window:									
Equity crises associated with banking crisis	23.08	13.26	8.60	0.48	0.43	0.50	–0.58	–0.45	0.04
Equity crises not associated with banking crisis	32.86	23.48	23.47	0.27	0.44	0.53	–0.17	–0.05	–0.16
24-month window:									
Equity crises associated with banking crisis	21.48	15.21	14.57	0.14	0.51	0.56	–0.26	–0.24	–0.04
Equity crises not associated with banking crisis	33.40	23.49	22.92	0.31	0.43	0.51	–0.21	–0.07	–0.15
Panel III: Using bank balance sheets									
12-month window:									
Equity crises associated with banking crisis	17.55*	18.27	17.88	0.43	0.30	0.37	0.18	–0.44	–0.70
Equity crises not associated with banking crisis	35.33	22.40	21.90	0.21	0.47	0.58	–0.36	–0.07	–0.05
24-month window:									
Equity crises associated with banking crisis	18.55*	18.80	18.88	0.55	0.47	0.39	0.19	–0.03	–0.50
Equity crises not associated with banking crisis	36.31	22.50	21.75	0.13	0.41	0.59	–0.41	–0.23	–0.09
Benchmarks	Returns	Skewness	Kurtosis						
Total sample	12.85	0.87	2.65						
1970s	6.08	0.67	1.41						
1980s	19.56	0.48	0.20						
1990s	10.98	0.35	–0.11						

*Indicates that results for twin crisis are significantly different from those during other crises (95%).

We repeat the same exercise for the twin crises identified earlier. In general, equity price increases in the period preceding the twin asset and banking crises were significantly higher than during our chosen benchmark periods. When using bank equity as our identification method, we find that equity price increases were slightly higher when a twin equity and banking crisis followed than when an isolated equity crisis followed, but again the difference was statistically insignificant. In contrast, when using the qualitative or the balance sheet methods, we obtain the opposite result, with twin crises following weaker equity price increases. No remarkable pattern is observed in either skewness or kurtosis. Hence, the available evidence is too weak to conclude that bubble periods are more likely to cause simultaneous problems in both stock markets and the banking sector.

Finally, Table 6 examines bank lending in the three years prior to the onset of an asset price crisis. Evidence of expanding bank lending prior to asset crises might be an indication of a developing asset price bubble. As suggested by Allen and Gale (1998a), this bubble could burst if investors suddenly believed future credit to be lower than previously expected.

The table shows that, on average, aggregate lending growth is higher one, two and three years before the start of the asset price crisis when compared with historical benchmarks. None of the differences are statistically significant, however. When comparing twin and non-twin crises, we observe some evidence of higher lending growth prior to the former. Note, however, that both the qualitative and the balance sheet criteria yield the opposite result when using a 12-month window, and that the differences are rarely significant. Hence, our evidence to support the theoretical result of Allen and Gale (1998a) is rather weak.

Table 6

Is there evidence of increased bank lending prior to an equity price crisis (Q6)?

	Average lending growth prior to crisis		
	One year	Two years	Three years
All equity crises	14.31	14.62	14.18
Panel I: Using bank equity			
12-month window:			
Equity crises associated with banking crisis	13.70	14.86	13.94
Equity crises not associated with banking crisis	11.03	11.70	11.94
24-month window:			
Equity crises associated with banking crisis	13.24	14.70	14.01
Equity crises not associated with banking crisis	11.28	10.67	10.71
Panel II: Using qualitative data			
12-month window:			
Equity crises associated with banking crisis	19.26	21.49	20.98
Equity crises not associated with banking crisis	13.78	13.88	13.45
24-month window:			
Equity crises associated with banking crisis	19.26	21.49	20.98
Equity crises not associated with banking crisis	13.78	13.88	13.45
Panel III: Using bank balance sheets			
12-month window:			
Equity crises associated with banking crisis	13.01	13.32	13.61
Equity crises not associated with banking crisis	14.76	15.07	14.38
24-month window:			
Equity crises associated with banking crisis	15.31	15.41	15.62
Equity crises not associated with banking crisis	14.43	14.55	13.86
Benchmarks			
Total sample	11.48		
1970s	15.07		
1980s	14.20		
1990s	6.05		

5. Conclusions

This paper examined the association between equity market crises and banking crises for 14 developed countries over the period 1970–99. We find the association to be relatively weak and not to be systematically related to the severity of the equity price collapse. Our empirical results do not permit us to conclude that periods of sharp equity price increases cause problems in both equity markets and the banking sector.

When looking at the effect of banking crises on the equity market, we observe mixed evidence of banking crises leading to large equity price falls, but cannot conclude that banking crises systematically cause large-scale liquidations of equity. Finally, we find only weak evidence of increased bank lending prior to equity market crises, as suggested by theoretical models of asset price bubbles and banking crises.

An important caveat pertains to all our results, which stems from the relatively small number of banking crises that have occurred in developed countries over the past three decades, the incomplete nature of our data set and the limitations of our methodology to accurately identify banking crises. Extending our sample to emerging market economies may yield stronger associations. For example, Glick and Hutchinson (1999) find that the association between banking and currency crises is stronger for financially liberalised emerging market economies than for the remaining countries (including both developed and less developed emerging countries). It will be equally important in future research to refine our banking crisis indicators.

Appendix A

Equity crises						
Country	Start	Crisis	Trough	End	Length (in months)	Price decline (in %)
Australia	Jan. 73	June 74	Sep. 74	Apr. 76	38	–60.12
	Oct. 80	Feb. 82	Mar. 82	July 83	32	–43.23
	Sep. 87	Oct. 87	Feb. 88	Oct. 91	48	–41.8
Canada	Oct. 73	Aug. 74	Sep. 74	May 78	54	–38.72
	Nov. 80	Feb. 82	June 82	May 83	29	–43.04
	July 87	Oct. 87	Nov. 87	Aug. 89	24	–24.26
	May 98	Aug. 98	Sep. 98	July 99	13	–25.37
Denmark	June 73	May 74	Nov. 74	Jan. 76	30	–42.11
	Jan. 84	Oct. 84	Oct. 84	June 88	52	–29.82
	July 91	Sep. 92	Oct. 92	Dec. 93	28	–33.26
France	Apr. 73	June 74	Sep. 74	Feb. 76	34	–52.67
	Feb. 76	Mar. 77	Apr. 77	May 78	26	–36.07
	Apr. 87	Nov. 87	Jan. 88	Jan. 89	20	–43.5
Finland	Apr. 89	Sep. 90	June 91	Apr. 93	47	–49.34
Germany	July 72	June 74	Sep. 74	Apr. 75	32	–34.4
	Apr. 86	Oct. 87	Jan. 88	Aug. 89	39	–47.77
	Mar. 90	Sep. 90	Sep. 90	Aug. 93	40	–33.47
Hong Kong	Feb. 73	Sep. 73	Nov. 74	Jan. 76	34	–89.53
	July 97	Jan. 98	Aug. 98	–	–	–60.09
Italy	June 73	Dec. 74	Sep. 75	Sep. 78	62	–53.29
	May 81	Oct. 81	June 82	Jan. 84	31	–40.5
	Aug. 86	Oct. 87	May 88	July 89	34	–41.53
Japan	Jan. 73	Sep. 74	Oct. 74	Jan. 76	35	–40.24
	Dec. 89	Sep. 90	Sep. 90	May 94	52	–46.65
Norway	Jan. 74	Sep. 74	Nov. 75	Mar. 79	61	–57.39
	Sep. 87	Nov. 87	Dec. 87	Mar. 89	17	–43.8
	July 90	Jan. 91	Nov. 91	Oct. 93	38	–42.83
Spain	Apr. 74	July 77	Oct. 77	Mar. 81	82	–63.01
	Sep. 89	Sep. 90	Sep. 90	July 93	44	–38.36
Sweden	Apr. 76	June 77	Nov. 77	Aug. 78	27	–36.18
	Sep. 87	Nov. 87	Nov. 87	Dec. 88	14	–32.38
	July 90	Sep. 90	Nov. 90	May 93	32	–36.79
United Kingdom	Aug. 72	Jan. 74	Nov. 74	Dec. 75	39	–68.71
	Jan. 76	Sep. 76	Oct. 76	Mar. 77	13	–28.78
	Sep. 87	Nov. 87	Nov. 87	Aug. 89	22	–33.79
United States	Dec. 72	Apr. 74	Sep. 74	Jan. 76	36	–48.39
	Nov. 80	Sep. 81	July 82	Nov. 82	23	–23.26
	Aug. 87	Nov. 87	Nov. 87	July 89	22	–30.04

Appendix B

Banking crises using qualitative identification method (after Glick and Hutchinson (1999))		
	Beginning	End
Canada	1983	1985
Denmark	1987	1992
Finland	1991	1994
France	1994	1995
Germany	1978	1979
Italy	1990	1995
Japan	1992	1997
Norway	1987	1993
Spain	1977	1985
Sweden	1990	1993
United Kingdom	1975	1976
	1984	1984
United States	1980	1992

Appendix C

Identification of banking crises using balance sheet data (using aggregate deposits (lines 24 + 25 or 251 from IFS)								
	Beginning of crisis	Crash	Trough	Recovery	Trigger	Duration of crisis (months)	Beginning to trough (using raw data)	Beginning to trough (using raw data)
							% change in deposits during crisis	% change in equity index
Australia	July 73	Aug. 74	Sep. 74	Apr. 79	2	68	10.65	–55.09
	Aug. 89	July 90	Dec. 91	Feb. 93	2	30	18.40	–0.25
	Mar. 93	Aug. 93	Aug. 93	Dec. 94	1.5	21	0.61	15.03
Canada	Dec. 81	Nov. 82	Feb. 84	Dec. 84	2	36	1.89	26.93
	Aug. 97	Oct. 98	Jan. 99	Apr. 99	2	20	3.27	8.68
Denmark	–	Jan. 71	Jan. 71	Nov. 71	1.5	–	–	
	Mar. 76	Mar. 78	Mar. 78	Oct. 79	1.5	31	12.54	–8.50
	Oct. 88	Dec. 89	Dec. 89	May 91	1.5	31	9.74	54.64
	July 91	Dec. 92	Dec. 92	Oct. 93	1.5	27	2.83	–30.47
	Dec. 93	Sep. 94	Mar. 95	Mar. 98	2	51	–13.04	–15.18
Finland	July 73	Sep. 74	Sep. 74	Apr. 79	2	70	23.55	.
	Aug. 89	Feb. 91	Dec. 91	Feb. 93	2	31	21.18	–54.18
	Mar. 93	Aug. 93	Aug. 93	Dec. 94	1.5	22	2.56	45.47
France	Feb. 79	Dec. 79	Dec. 80	Dec. 83	1.5	58	24.90	31.48
	Sep. 84	Mar. 88	Sep. 88	Mar. 90	1.5	66	27.65	105.24
	Mar. 90	May 91	Dec. 91	Mar. 93	2	36	3.62	–9.03
Germany	Nov. 78	June 80	July 80	Mar. 82	1.5	40	5.47	–9.07
	Sep. 90	June 91	Sep. 91	Dec. 93	1.5	39	4.27	17.71
	Jan. 94	Dec. 94	Apr. 95	Dec. 96	2	35	0.12	–8.91
Italy	May 92	Jan. 95	Mar. 95	July 96	2	50	12.26	39.55
	July 96	Mar. 97	Dec. 97	–	2	–	–4.20	66.30
Japan	Sep. 90	Apr. 91	Nov. 92	Nov. 94	2	50	0.84	–11.50
	Jan. 95	Feb. 96	Apr. 96	Aug. 96	2	19	3.29	19.10
	Aug. 96	Mar. 97	Mar. 97	Feb. 98	1.5	18	–0.86	–8.27
Norway	Dec. 84	Dec. 86	Dec. 86	Oct. 87	1.5	34	17.71	26.80
	Jan. 88	Nov. 88	Mar. 92	Oct. 92	1.5	57	18.38	67.47
	Dec. 92	Dec. 93	Dec. 93	Feb. 96	2	38	–1.86	52.15
	Dec. 96	Feb. 97	Jan. 98	Jan. 99	2	25	–7.33	14.53
Spain	Aug. 82	Jan. 83	Oct. 83	Jan. 85	2	29	–2.90	7.77
	Feb. 86	Jan. 87	Jan. 87	Jan. 89	1.5	35	4.06	60.26
	Jan. 91	Feb. 97	Oct. 97	Oct. 98	2	93	46.53	179.14
Sweden	Sep. 86	Mar. 90	Oct. 90	Mar. 91	2	54	20.93	32.69
	July 91	Sep. 92	Sep. 92	Oct. 93	2	27	–4.31	–36.05
	Oct. 93	Jan. 95	Feb. 95	Mar. 96	2	29	0.65	5.13
	May 96	Feb. 98	Mar. 98	Mar. 99	2	34	0.66	91.02
United Kingdom	Nov. 89	Dec. 91	Jan. 92	Jan. 94	2	50	15.36	12.48
	Jan. 96	Nov. 97	Mar. 98	–	1.5	–	16.71	56.09
United States	Dec. 86	Nov. 87	Dec. 87	Dec. 89	2	36	0.53	0.61
	Sep. 90	July 94	Mar. 95	Feb. 96	2	65	14.95	65.70

Appendix D

Identification of banking crises using bank equity data								
	Beginning of crisis	Crash	Trough	Recovery	Trigger	Duration of crisis (months)	% price decline during crisis	% price decline during crisis
							Bank equity	Total equity
Australia	Aug. 87	Oct. 87	Nov. 87	May 88	1.5	9	–28.63	–36.65
	Jan. 90	Sep. 90	Dec. 90	June 93	2	41	–38.30	–20.41
Canada	Aug. 75	Apr. 77	May 77	Apr. 78	1.5	32	–20.06	50.20
	Nov. 80	Jan. 82	June 82	Feb. 83	2	27	–41.16	–43.04
	Apr. 83	May 84	June 84	May 85	1.5	25	–24.97	–4.54
	June 87	Oct. 87	Nov. 87	Jan. 89	1.5	19	–20.92	–20.98
	July 89	Apr. 90	Oct. 90	Nov. 81	2	28	–29.87	–19.97
	May 98	Aug. 98	Sep. 98	–	2	–	–38.02	
Denmark	Dec. 83	Mar. 84	June 84	June 85	1.5	18	–29.37	–19.64
	Dec. 85	July 86	July 86	June 88	1.5	30	–29.51	–17.90
	Nov. 89	Dec. 90	Oct. 92	Sep. 93	2	46	–55.19	–26.20
France	Apr. 90	Sep. 90	Dec. 90	Nov. 92	1.5	31	–36.71	–26.13
	Dec. 93	Aug. 95	Sep. 95	Feb. 97	1.5	50	–34.93	–16.92
	July 98	Sep. 98	Sep. 98	–	2	–	–51.31	
Germany	Apr. 86	May 87	Jan. 88	Nov. 89	2	43	–49.47	–47.77
	May 98	Sep. 98	Sep. 98	–	2	–	–35.05	
Hong Kong	July 81	Sep. 82	Nov. 82	Dec. 84	2	41	–55.79	–57.97
	Sep. 87	Nov. 87	Nov. 87	Dec. 89	1.5	27	–41.93	–45.78
	Jan. 94	Jan. 95	Jan. 95	Jan. 96	1.5	24	–42.32	–36.72
	July 97	May 98	Sep. 98	–	2	–	–54.52	
Italy	May 81	Oct. 81	June 82	July 85	2	49	–51.09	–40.50
	Mar. 86	Dec. 87	May 88	May 89	1.5	37	–51.75	–33.43
Japan	Dec. 89	Sep. 90	Sep. 90	June 96	2	77	–47.75	–46.65
	June 96	Oct. 97	Sep. 98	–	2	–	–62.98	
Spain	Aug. 89	Mar. 90	Sep. 92	July 93	2	47	–48.01	–42.33
	July 98	Sep. 98	Sep. 98	–	2	–	–42.85	
Sweden	Aug. 89	June 92	Nov. 92	Aug. 93	2	48	–87.00	–21.43
	June 96	Oct. 97	Sep. 98	–	1.5	–	–	
United	Jan. 69	July 69	Mar. 70	Mar. 71	1.5	26	–25.35	
Kingdom	Dec. 72	Feb. 74	Nov. 74	Nov. 75	2	35	–69.68	–67.76
	Jan. 76	Nov. 76	Nov. 76	Apr. 78	1.5	27	–25.03	–24.10
	Sep. 87	Oct. 87	Nov. 87	Nov. 89	2	26	–35.29	–33.79
	Jan. 90	Sep. 90	Oct. 90	Mar. 91	1.5	9	–26.28	–12.14
	Jan. 94	May 94	May 95	Sep. 95	1.5	20	–8.83	–6.07
	Feb. 98	Aug. 98	Sep. 98	Mar. 99	2	13	–35.57	–12.29
United	Aug. 87	Oct. 97	Nov. 87	July 89	2	23	–29.35	–30.04
States	Sep. 89	Apr. 90	Oct. 90	Aug. 91	2	23	–42.63	–12.27
	Apr. 98	Aug. 98	Sep. 98	Apr. 99	1.5	12	–26.62	–7.68

Bibliography

Allen, Franklin and Douglas Gale (1998a): “Bubbles and Crises”. Mimeo, University of Pennsylvania.

Allen, Franklin and Douglas Gale (1998b): “Optimal Financial Crises”. *Journal of Finance*, 53(4), pp. 1245-84.

Allen, Franklin and Douglas Gale (1999): “Financial Contagion”. Mimeo, University of Pennsylvania.

Berg, Andrew and Catherine Pattillo (1999): “Are Currency Crises Predictable? A Test”. *IMF Staff Papers*, 46, pp. 107-38.

Bernanke, Ben and Mark Gertler (1999): “Monetary Policy and Asset Price Volatility”. Paper presented at Jackson Hole Conference on “New Challenges for Monetary Policy,” 26–28 August.

Borio, Claudio E V, N Kennedy and S Prowse (1994): “Exploring aggregate asset price fluctuations across countries: measurement, determinants and monetary policy implications”. *BIS Economic Papers*, No. 40.

Chari, V V and Ravi Jagannathan (1988): “Banking panics, information, and rational expectations equilibrium”. *Journal of Finance*, 43(3), pp. 749-61.

Clare, Andrew and Richard Priestley (1999): Mimeo, Norwegian School of Management.

Davis, E Philip (1999): “Financial Data Needs for Macroprudential Surveillance – What are the Key Indicators of Risks to Domestic Financial Stability?” Bank of England, *Handbooks in Central Banking Lecture Series*, No 2.

Davis, E Philip (1995): *Debt, Financial Fragility and Systemic Risk*. Clarendon Press, 2nd edition.

Demirgüç-Kunt, Asli and Enrica Detragiache (1998a): “The Determinants of Banking Crises in Developing and Developed Countries”. *IMF Staff Papers*, 45(1), pp. 81-109.

Demirgüç-Kunt, Asli and Enrica Detragiache (1998b): “Financial Liberalization and Financial Fragility”. *IMF Working Paper 98/83*.

Diamond, Douglas W and Philip H Dybvig (1983): “Bank runs, deposit insurance, and liquidity”. *Journal of Political Economy*, 91(3), pp. 401-19.

Eichengreen, Barry, Andrew K Rose and Charles Wyplosz (1996): “Contagious Currency Crises”. *NBER Working Paper* No. 5681.

Gertler, Marc, Marvin Goodfriend, Otmar Issing and Luigi Spaventa (1998): “Asset prices and monetary policy. Four views”. CEPR and BIS.

Glick and Hutchinson (1999): “Banking and Currency Crises: How Common Are Twins?” Mimeo, IMF.

Gorton, Gary (1988): “Banking panics and business cycles”. *Oxford Economic Papers*, 40(4), pp. 751-81.

Greenspan, Alan (1999): “New challenges for monetary policy”. Speech at Jackson Hole conference on “New Challenges for Monetary Policy”, August 27.

Hardy, Daniel C and Ceyla Pazarbasioglu (1998): “Leading Indicators of Banking Crises: Was Asia Different?” *IMF Working Paper 98/91*.

International Monetary Fund (1998): “World Economic Outlook”. Washington DC.

Kaminsky, Graciela, Saul Lizondo and Carmen Reinhart (1998): “Leading Indicators of Currency Crises”. *IMF Staff Papers*, 45, pp. 1-48.

Kaminsky, Graciela and Carmen Reinhart (1999): “The Twin Crises. The Causes of Banking and Balance-of-Payment Problems”. *American Economic Review*, 89(3), pp. 473-500.

Kaufman, George G (1999): “Banking and Currency Crises and Systemic Risk: A Taxonomy and Review”. Mimeo, Loyola University Chicago.

Kaufman, George G (1998): “Central Banks, Asset Bubbles, and Financial Stability”. *Working Paper 98-12*, Federal Reserve Bank of Chicago.

Lindgren, Carl-Johan, Gillian Garcia and Matthew I Saal (1996): *Bank soundness and Macroeconomic Policy*. IMF.

Marshall, David (1998): “Understanding the Asian crisis: Systemic risk as co-ordination failure”. *Economic Perspectives*, Federal Reserve Bank of Chicago, pp. 13-28.

Mishkin, Frederic S (1994): “Preventing Financial Crises: An International Perspective”. *NBER Working Paper*, No. 4636.

Patel and Sarkar (1998): “Crises in Developed and Emerging Stock Markets”. *Financial Analysts Journal*, pp. 50-61, November/December.

Sachs, Jeffrey, Aaron Tornell and Andres Velasco (1996): “Financial Crises In Emerging Markets: The Lessons From 1995”. *Brookings Papers On Economic Activity: 1*, pp. 147-215.

Schinasi, Garry J and Monica Hargraves (1993): “Boom and Bust in Asset markets in the 1980s: Causes and Consequences”. Staff Studies for the World Economic Outlook, IMF, pp. 1-27.

Vickers, John (1999): “Monetary Policy and Asset Prices”. *Bank of England Quarterly Bulletin*, November.

Early warning systems for currency crises

Peter J G Vlaar[1]

1. Introduction

In recent years, the frequency of currency crises in developing countries seems to have increased. Moreover, the consequences of these financial crises have probably worsened, not only for the country concerned, but also for other countries in the region, due to increased international trade and capital flows. This has encouraged research on the prediction of currency crises. In this paper, this research is summarised and a new approach to modelling currency crises is proposed.

In order to predict currency crises, it is of course essential to define what a currency crisis is. In the theoretical literature, currency crises are defined only for fixed exchange rate regimes. A crisis is identified as an official devaluation or revaluation, or a flotation of the currency. This definition is probably too strict to be useful for our purposes. Many currency crises involve currencies that are not formally fixed to one currency or a basket of currencies, but are allowed to float within certain margins. Even currencies that are allowed to float freely might be subject to a disruptive depreciation due to a speculative attack. Moreover, a small official devaluation in a tranquil period does not have to be disruptive as it may bring the real exchange rate more into line with fundamentals. Such an action might very well preclude future speculative attacks, and should not be identified as a crisis. For most purposes, the size of the depreciation is what matters, not so much whether this depreciation is caused by an official policy move or otherwise. Therefore, many empirical studies define a currency crisis as a large (either nominal or real) depreciation. Here, the problem arises of deriving the appropriate threshold above which a depreciation should be labelled a crisis. Another issue concerning the definition of a crisis is whether or not to include unsuccessful speculative attacks. Authorities may react to a currency attack by means of direct intervention in the foreign exchange market, or by raising interest rates. These attacks might also be included in the crisis definition as the necessary policy actions might be disruptive for the economy as well. In addition, from an investor's point of view, including unsuccessful speculative attacks might be useful as unsuccessful attacks also indicate vulnerability.

In this paper, a currency crisis indicator, based on monthly nominal exchange rate depreciations relative to the US dollar and depletions of official reserves, is constructed for emerging markets economies. Interest rates are not included in the index as interest rate data for emerging countries are not always available and/or reliable. The main innovation in our modelling approach is that we model the crisis index itself, instead of a zero-one variable representing index values below or above a certain threshold. The proposed model has two regimes – one for tranquil and one for crisis episodes – where the probability of ending up in the crisis regime depends on the economic circumstances. In the crisis regime, both the mean depreciation and the volatility are larger. The modelling technique resembles the one introduced in Vlaar (1998), where a two-regime model was used to predict weekly exchange rate changes within the European Monetary System, but is extended in two respects. First, not only the probability to end up in the crisis regime, but also the mean depreciation and the volatility in this regime are allowed to differ with economic conditions. Second, the model is adjusted to allow for panel data estimation.

[1] Econometric Research and Special Studies Department, Netherlands Bank. I thank Peter van Els and seminar participants at the Netherlands Bank and the Autumn Meeting of Central Bank Economists at the BIS for valuable comments and discussions.

The continuous modelling approach has several advantages. First, by using the index itself, we do not discard information regarding the severity of a crisis. Therefore, large index values have more impact on the model than values just above the (arbitrarily set) crisis threshold. Second, as the continuous crisis variable varies between observations, there is no need to include many crisis episodes in the sample in order to estimate the model. Consequently, we can concentrate on emerging markets without having to include developed countries in the sample as well. Finally, the continuous modelling approach makes it possible to distinguish between variables that have an effect on the probability of a crisis and those that affect the severity of crises.

The rest of this paper is organised as follows. In Section 2, some theoretical background on currency crises is given. Section 3 summarises the main results from the empirical literature. In Section 4, the new modelling approach is described. Section 5 contains the estimation and forecast results, and Section 6 concludes. The Appendix describes the data.

2. Theoretical considerations

As to the reasons for currency crises, the "first generation" models of, for example, Krugman (1979) focus on inconsistencies between an exchange rate commitment and domestic economic fundamentals, such as excess creation of domestic credit, typically prompted by a fiscal imbalance. In these models, currency crises occur because international reserves are gradually depleted. The model fixes the timing of a currency attack such that the remaining reserves before the attack are just enough to satisfy the foreign currency demands of market participants during the attack.

The "second generation" models of, for example, Obstfeld (1986) view currency crises as shifts between multiple monetary equilibria in response to self-fulfilling speculative attacks. Consequently, the timing of the attack can no longer be determined, as it is no longer unique. In these second generation models, currency attacks can take place even though current policy is not inconsistent with the exchange rate commitment. The attacks can nevertheless be successful because the costs of maintaining a currency peg, in the form of high domestic interest rates, rise in response to the attack. In this framework, speculative attacks become more likely if high interest rates become more problematic. One reason for this might be economic slowdown or high unemployment rates. Another might be a weak domestic banking sector (Obstfeld (1995)). Raising interest rates increases short-term funding costs for banks, whereas the higher proceeds from loans might be of little importance to bank profits due to the longer maturity on average of loans relative to deposits and the increased probability of bad loans triggered by the rise in the interest rate.

This is one way banking and currency crises might be related. If there is an implicit government commitment to bail out troubled banks, bank runs might also lead directly to a currency crisis if the increased liquidity which results from the government bailout is inconsistent with the fixed parity (Velasco (1987), Calvo (1998)). The causality between banking and currency crises might also run in the other direction, however, for instance if the domestic banking sector is exposed to exchange rate risk due to short-term foreign lending (Chang and Velasco (1998)). Indeed, Kaminsky and Reinhart (1996) find evidence of both directions, although during most twin crises the banking crisis is preceded by the currency crisis.

3. Empirical literature

Kaminsky et al. (1998) summarise the results of 28 empirical studies on currency crises that have appeared over the last 20 years. Although the studies differ widely in crisis episodes considered and methodologies used, some general conclusions can be drawn. First, in order to explain all currency crises a wide variety of variables is needed. This is because crises can have many different causes. Some variables do seem to have predictive power for many crises, however. In particular, real exchange rates and international reserves are included in many studies and found significant most of the time. Other variables that seem to do well, although the limited number of studies considering them precludes firm statements, are the domestic inflation rate and domestic credit growth. Current account deficits on the other hand are usually not found to have a significant impact. Rather than replicating the results by Kaminsky et al., we choose to highlight just a few typical studies and to concentrate on emerging market economies. The studies will be categorised by the methodology used.

3.1 The signal approach

The signal approach is primarily a bivariate method. For each variable the average level (or growth) in the period preceding the crises is compared to that in tranquil periods. If the variable behaves differently before a crisis, an extreme value for this variable provides a warning signal. The question of what value should be considered extreme in this context is solved by weighing the percentage of crises predicted against the percentage of false signals. The threshold level can either be the same for all countries, or be based on the country-specific empirical distribution of the variable. Given the warning signals of the individual variables, a composite leading indicator can be constructed as a weighted average of the individual signals.

In this procedure, both the crisis indicator and the explanatory variables are transformed into dummies, namely larger or smaller than a given threshold. This procedure probably gives the best results if there is a clear distinction between crisis episodes and periods of tranquillity. Regarding the crisis indicator, this is probably true if only the most severe crises are above the threshold or if the crisis definition is related to a currency peg. However, in most studies the number of severe currency crises is limited, and less serious depreciations are also labelled as crises. In that case, there is no clear distinction between observations just above and those below the crisis threshold. Concerning the explanatory variables, disregarding the exact value of the variable seems inefficient as, for instance, a current account deficit twice the value of the threshold seems to provide a stronger signal than a deficit just above it. If the individual signals are combined to compute a composite leading indicator, this inefficiency leads to inferior results. Another problem that arises in combining the signals is that the optimal weights for the individual signals cannot easily be assessed if the signals are correlated. If, however, one is primarily interested in finding vulnerabilities, without being particularly interested in exact probabilities, this method may be appropriate since it immediately points to the most important variables. This is particularly helpful for determining appropriate economic policy actions.

Kaminsky et al. (1998) use a signals approach to predict currency crises using monthly data for a sample of 15 developing and five industrial countries during 1970–95. In their study, a currency crisis is defined to occur when a weighted average of monthly percentage nominal depreciations (either with respect to the US dollar or the Deutsche mark) and monthly percentage declines in reserves exceeds its mean by more than three standard deviations for that country.[2] For 15 variables, based on economic priors and data availability, they compare the levels in the 24 months prior to the crises with values in tranquil periods. For each variable, an optimal threshold value is computed, above which the variable gives a signal for a crisis in the coming 24 months. The threshold levels are computed as a percentile of the distribution of the variable *by country* in such a way that the noise-to-signal ratio is optimal. The variables that have most explanatory power are (1) the real exchange rate deviation from a deterministic trend, (2) the occurrence of a banking crisis, (3) the export growth rate, (4) the stock price index growth rate, (5) M2/reserves growth rate, (6) output growth, (7) excess M1 balances, (8) growth of international reserves, (9) M2 multiplier growth, and (10) the growth rate of the domestic credit to GDP ratio.

Country-specific threshold levels for the economic variables have the advantage that national elements are taken into account. However, as the same percentile is used for all countries, it also implies that, within sample, all variables signal the same number of crises per country. Although only countries that experienced currency crises are included in the sample, this artefact seems undesirable. The real

[2] Weights, mean depreciations and volatility are calculated separately for high inflation episodes, defined as months preceded by a six month period with more than 150% inflation.

exchange rate is by far the most successful indicator. However, this result might be partly spurious as the deviation of the bilateral real exchange rate from a deterministic trend is used. Consequently, any real overvaluation according to this definition has to lead to either a depreciation or a lower inflation rate at home than in the reference country.

Berg and Pattillo (1998) evaluated their approach with respect to predicting the Asian crisis out of sample, and found mixed results. Most (68%) crises were not signalled in advance, and most (60%) of the signals were false. Nevertheless, the predictions were better than random guesses, both economically and statistically. The results improve slightly (also in-sample) if the current account relative to GDP and the level of the M2/reserves ratio are included. They also compare the ranking of severity of currency crises in 1997 with the ranking of vulnerability according to predicted probabilities of crisis. The composite leading indicator can explain 28% of the variance. If the current account/GDP and M2/reserves ratios are also included, this rises to 36%.

3.2 Limited dependent regressions

In the limited dependent regression models (logit or probit models), the currency crisis indicator is modelled as a zero-one variable, as in the signals approach. The explanatory variables are not transformed into dummy variables however, but are usually included in a linear fashion. The logit or probit functions ensure that the predicted outcome of the model is always between zero and one. The regression approach has several advantages compared with the signals approach. First of all, the prediction of the model is easily interpreted as the probability of a crisis. Moreover, as the method considers the significance of all the variables simultaneously, the additional information of new variables is easily checked. A disadvantage of this approach might be that the impact of an individual variable is less easily detected. Due to the non-linear logit or probit function, the contribution of a particular variable depends on all the other variables as well. A practical problem of using this strategy to model currency crises is that the number of crises is usually limited. Consequently, there are only a few ones in the sample, compared with a large number of zeros, resulting in poor estimation results. In order to increase the number of ones, many studies combine data from industrialised and emerging market economies.

Frankel and Rose (1996) use the probit model to estimate the probability of crisis in an annual sample of 105 developing countries covering 1971–92. A crisis is defined as a depreciation of at least 25%, exceeding the previous year's depreciation by at least 10%. The use of annual data has the advantage that more variables are available, for instance regarding fiscal positions and external debt. Moreover, compared with monthly data, the balance between zeros and ones in the sample is probably better. They find 69 crashes in 780 observations. They present several specifications, and conclude that the probability of crisis increases when output growth is low, domestic credit growth is high, foreign interest rates are high, foreign direct investment as a proportion of total debt is low, reserves are low, or the real exchange rate is overvalued. The results for output growth, the real exchange rate and reserves were not robust across specifications, however. Berg and Pattillo (1998) evaluate the results of Frankel and Rose. Using a cutoff probability of 25% , only 17 out of 69 crises are rightly predicted within sample, whereas 33 out of 711 tranquil periods are wrongly predicted. They argue that one of the reasons for these rather poor results might be that the country group is too diverse. They proceed with a smaller group of larger (emerging) markets over the sample 1970–96. Given results in other studies, the reserves/M2 and reserves/short-term debt ratios are also included as explanatory variables, where only the former shows significant results. For this specification, 38 out of 60 crises and 342 out of 383 tranquil periods are rightly predicted. The out-of-sample results are still disappointing, however. According to the definition of Frankel and Rose, there were no crises in 1997! This clearly indicates one of the problems with yearly data if a crisis takes place around the end of the year. If the ranking of their crisis index in 1997 is compared with the ranking of predicted probabilities of crisis, only 6% of the variance is explained in the original specification. For the modified model the percentage is even lower, 5%. In both cases, the model does not perform significantly better than random guesses.

Berg and Pattillo (1998) also use a probit model to study currency crises. They base themselves on the data and crisis definition of Kaminsky et al (1998), augmented by the current account and the ratio of M2 over reserves, as described above. In their regression model, not only the crises themselves are labelled “one”, but also the 23 months prior to the crisis. Economically, this procedure has the advantage that the optimal model is sought that signals a crises two years in advance. Of course, this also means that the origins of a crisis are supposed to be visible two years in advance. Statistically, the procedure strongly improves the balance between the zeros and the ones in their monthly data set. They investigate whether a threshold value for the explanatory variables, as in the signals approach, improves on a linear specification. This turns out not to be the case. The variables that have most explanatory power are (1) the deviation of the real exchange rate from trend, (2) the current account, (3) reserve growth, (4) export growth, and (5) the ratio of M2 to reserves. In the model, not the variables themselves but the percentiles of the country-specific distribution of the variables are included. Using a cutoff probability of 25%, the model signals 48% of crises and 84% of tranquil periods correctly, within sample. Out of sample, the results are even better: 80% of crises and 79% of tranquil periods are correctly called. The prediction of the ranking of crisis severity in 1997 is not very successful. Only 23% of the variance is explained, slightly worse than the signals approach of Kaminsky et al. (1998), though still significantly better than random guesses.

The “Event Risk Indicator” by JP Morgan (1998) is based on a logit regression on monthly observations for 25 industrial or emerging countries over the sample 1980–97. Their crisis indicator is defined as a monthly real depreciation of the key bilateral exchange rate of over 10%. Consequently, this crisis definition excludes unsuccessful speculative attacks. As their basic goal is to find a model that can be used to predict profitable months to invest in weak currencies, this choice is reasonable. They balance the number of crises and tranquil periods in their sample by including only three tranquil periods per country. The explanatory variables for these three periods are calculated as: first, the average value of the variables over the estimation sample (1980–94), excluding the months in which there was a crisis, the month before, and the month after these crises; second, the average plus one standard deviation over the same sample; and third, the average minus one standard deviation. As a consequence, the predictions of the model are not directly interpretable as probabilities of a currency crash. The key factor behind currency crashes is supposed to be lack of competitiveness, included in the model as an overvalued real exchange rate (a dummy variable that can take the values one to four, based on the average value of the real exchange rate in the last two years, relative to the average value in the ten years before). As the model is used to select profitable investment months in weak currencies, predicting the exact timing of a crisis is extremely important. This timing is supposed to depend on two factors. First, the credibility of the government’s commitment to defend the exchange rate, which is related to expected economic growth (modelled by means of the three-month rise in stock prices) and the size of foreign exchange reserves (relative to foreign debt). Second, the force of financial contagion, reflected in global risk appetite and local currency crash clustering. Global risk appetite is measured as the correlation between return and risk (reflected in high interest rates and an overvalued currency) over the last three months. Both the one month lagged and the seven months lagged six-month changes in this variable are included, as currency crashes are most likely if risk appetite changes from positive to negative. The local currency crashes variable is computed as a weighted number of currency crashes in the relevant currency block (Deutsche mark or US dollar) in the last six months, where recent crashes are given a higher weight than earlier ones.

The regression results show that the six-month change in risk appetite is the most important explanatory variable, followed by the number of local crashes and the reserves/debt ratio. The real exchange rate is just significant at the 5% level, the six-month change in risk appetite lagged seven months at the 10% level, and the change in stock prices at the 15% level. Using a cutoff level of 40%,[3] 31 out of 37 crises and 69 out of 74 quiet periods are correctly predicted within sample. The model also seems to predict quite well out of sample, as an investment strategy based on the model predictions outperforms a passive, or random, investment strategy on average. According to the authors, the results of the model are most sensitive for the clustering variable, followed by the current

[3] Over the period January 1988 to September 1997, this cutoff point would signal the risk of a crisis 29% of the time.

and lagged changes in risk appetite. Notwithstanding the importance of current sentiment, they also claim that the model signals all the major first crashes, including Mexico (December 1994), the ERM (September 1992), and Thailand (July 1997). This is surprising as only lagged variables are used in the model, and some of these crises came as a complete surprise to the market, thereby precluding the importance of contagion variables.

3.3 Severity of crisis indicators

A third category of models is not directly aimed at predicting the timing of currency crises, but at predicting which countries are going to be hit hardest, given the occurrence of a crisis somewhere in the world. If the timing of currency crises is largely unpredictable, for instance due to the importance of market sentiment, and the behaviour of financial markets during an international crisis is supposed to be different from normal behaviour, this strategy might be most fruitful. The idea is to define a crisis index (for instance based on depreciations and international reserve losses), spanning the whole period during which international markets were under stress, for a cross-section of countries. The differences between countries in the magnitude of this crisis index are subsequently explained by variables representing the economic situation at the onset of the crisis. This can be done by simple cross-section regression analysis. Usually, only one crisis episode is considered at a time, but a panel of crisis episodes can be used as well.

Sachs et al. (1996) use this framework to explain the severity of currency crises during the Mexican crisis of December 1994 (the so-called Tequila effect). They examine data on a cross-section of 20 emerging markets. Their crisis index is defined as a weighted average of the percentage decrease in reserves and the percentage depreciation of the exchange rate, from November 1994 to April 1995. They claim that only countries that were already vulnerable were hit by the Mexican crisis. Only three factors are essential for measuring vulnerability: an overvalued real exchange rate, measured as the real appreciation between the average 1986–89 level and the one over 1990–94; a weak banking system, measured by the four-year growth in credit to the private sector; and low levels of international reserves relative to M2. It turns out that only the combination of weak fundamentals (real overvaluation or weak banks) and relatively low reserves induced a crisis. They also investigate the influence of investment, savings, current accounts, the size of capital inflows, and fiscal policy stances, but these variables do not improve the results. Depending on the window over which the crisis index is calculated, their model can explain 51% to 71% of the variation in the crisis index over the Mexican crisis. Berg and Pattillo (1998) investigate whether the same equation can explain variations in the severity of crises during the Asian crisis. Unfortunately this is not the case. Even the results for the Mexican crisis turn out to be sensitive to minor revisions. Including three more countries changes the coefficients significantly. This sensitivity is probably due to small-sample problems. They estimate a model with seven variables, whereas they have only 20 observations. When the original equation, or slightly modified versions estimated on the Mexican crisis, is applied to the Asian crisis, at most 5% of the rankings are explained. When the same specification is re-estimated with data from the Asian crisis, the coefficients change significantly, and the real exchange rate is no longer significant. This equation can explain 21% of the variance in rankings (within sample). Tornell (1999) challenges these poor results. Using a model very similar to the one in Sachs et al. (1996), he concludes that banking weakness, real appreciation and international liquidity can explain both crises.[4] When estimated on data of the Mexican crisis only, the out-of-sample prediction of the Asian crisis still explains 24% of the variance in ranking. The fact that this result is not robust for minor changes in, for instance, the definition of the explanatory variables, raises serious doubts about the applicability of the model as a prediction device, however.

These problems are again confirmed by Bussière and Mulder (1999). They investigate the factors behind the depth of the 1994 and 1997 crises, and whether these can explain the 1998 Russian crisis.

[4] Both models include dummy variables for weak verses strong fundamentals (based on the real exchange rate and credit growth), and high verses low reserves. The results are especially sensitive to changes in the definition of the threshold levels for these dummy variables.

For this purpose they estimate a model using a panel of 22 emerging markets for the 1994 and 1997 crises. As explanatory variables they compare those used by Tornell (1999) with the ones included in the early warning system (EWS) model of the IMF (Borenzstein et al. (1999)).[5] The results strongly favour the variables of the latter study. Within sample, the explanatory power of the two models is about the same. Out of sample, however, the ranking of vulnerability according to Tornell's model turns out to be *negatively* correlated with the severity of crises in the aftermath of the Russian moratorium in August 1998. The EWS-based model results in a significant positive correlation (0.56). This model only includes three variables: the four-year growth in the real exchange rate, the current account/GDP ratio, and the short-term debt/reserves ratio, with the latter being by far the most significant. Other variables that were investigated, but found insignificant, are export growth, reserve changes (both are included in the EWS model), credit growth, current account minus foreign direct investment over GDP, M0, M1 or M2 over reserves, and short-term debt over GDP. The one variable that does have a positive impact is the availability of an IMF programme. The presence of an IMF-supported programme significantly reduces the depth of a crisis. From these results, the authors conclude that all three crises are primarily liquidity-driven, as opposed to solvency-driven. Whether the model can also be used to predict the next crisis remains to be seen. One of the problems relates to the availability of data. The authors include the last available observation of the explanatory variables before the starting point of the crises. This practice results in data being included that were not available to the market before the crisis. Especially with respect to short-term debt, the inclusion of the end-June 1997 and end-June 1998 positions is dubious as these figures only became available in November, whereas the crises started in July/August.

Glick and Rose (1998) use cross-sectional data on both industrial and developing countries (161 countries in total) for five different currency crises (1971, 1973, 1992, 1994 and 1997) to explain contagion. The inclusion of a large number of countries reduces the small-sample problem, but at the expense of allowing for more heterogeneity in the sample. The crisis episodes are investigated separately, not as a panel. They find strong evidence that trade linkages explain regional patterns of currency crises for all five periods. Domestic macroeconomic factors do not consistently help in explaining the cross-country incidence of speculative attack.[6] As no regional variable other than trade relations is included in the regressions, it is not clear whether trade relations really *cause* contagion, or whether the trade variable simply picks up the regional preferences of international investors. If the latter phenomenon is indeed dominant, diversifying trade patterns won't shelter countries from regional currency crises.

4. A new approach

The three approaches just discussed all have their disadvantages. The signals and limited dependent approaches define a currency crisis as a discrete event, which is doubtful for marginal crises, and disregards the depth of the crisis. The severity of crisis method only uses crisis observations, thereby completely disregarding the timing of a crisis, and possible information from tranquil periods. In this chapter, we propose a method that combines elements of the limited dependent and severity of crisis methods. As in the latter approach, we model a continuous crisis index, in this case a weighted average of the monthly depreciation of the exchange rate and of the monthly percentage decline in international reserves. In contrast to these models however, we consider not only crisis episodes but all available observations. Thus, it is assumed that tranquil periods also provide information regarding the

---

5 This model is based on Berg and Pattillo's (1998) model. The main difference is that the short-term debt/reserves ratio is included instead of the M2/reserves ratio.

6 Only inflation seems to matter during all five crises. Real growth significantly *increased* the severity of all but the 1992 crisis. Other variables included are credit growth (significant in 1994), government budget over GDP (significant in 1971 and 1973), current account over GDP (significant in 1994), and M2 over reserves (some influence in 1973 and 1994). All coefficients widely vary across crisis periods. In a probit regression, none of the macroeconomic variables is significant in any of the five crisis episodes considered.

vulnerability of individual currencies. The fact that vulnerabilities materialise primarily during crises is modelled by means of a model with two regimes, one for normal and one for unexpectedly volatile periods, where the latter regime is characterised by, on average, larger depreciations and extra volatility, which are common to crises. Unlike than with the limited dependent models, the definition of crisis periods is not imposed beforehand, but is the outcome of a stochastic process. The weaker the fundamentals of a country, the higher the probability of entering the volatile regime.

The empirical model can be described by the following six equations:

(1) $$I_{it} = X1_{it}\beta_1 + \lambda_{it}\vartheta_{it} + \varepsilon_{it}$$

(2) $$\varepsilon_{it} \sim (1-\lambda_{it})N(-\lambda_{it}\vartheta_{it}, h_{it}) + \lambda_{it}N((1-\lambda_{it})\vartheta_{it}, h_{it}+\delta_{it})$$

(3) $$h_{it} = X2_{it}\beta_2$$

(4) $$\lambda_{it} = \exp(X3_{it}\beta_3)/(1+\exp(X3_{it}\beta_3))$$

(5) $$\vartheta_{it} = X4_{it}\beta_4$$

(6) $$\delta_{it} = X5_{it}\beta_5$$

The first equation describes the evolution of the crisis indicator (I_{it}) for country *i* at time *t*. It consists of three parts: a linear part for normal periods, a non-linear part related to crisis episodes, and a stochastic error term. The distribution of the error term is described in equation (2). Conditional on being in the normal regime, which has probability $(1-\lambda_{it})$, the innovation is normally distributed with expectation $-\lambda_{it}\vartheta_{it}$ and variance h_{it}, whereas in the volatile regime the mean and variance are higher by ϑ_{it} and δ_{it} respectively. Note that the expectation of the combined process is zero. The volatility in the normal regime is described by equation (3). The probability of entering the volatile regime is estimated in the familiar logit form (equation (4)). Equations (5) and (6) describe, respectively, the additional expected depreciation (ϑ_{it}) and variance (δ_{it}) in the volatile regime. The parameters in this model (the β_is) are estimated by maximum likelihood. In order to ensure that the conditional variances are always positive, β_2 and β_5 and the corresponding economic variables $X2_{it}$ and $X5_{it}$ are restricted to being non-negative.

Apart from the second equation, economic variables, denoted by $X1_{it}$ to $X5_{it}$, might enter all equations. The interpretation of their influence differs between equations, however. The economic variables in the first equation describe the evolution of the crisis indicator in normal periods. Candidate variables are past changes in exchange rates and international reserves; this enables us to model the positive autocorrelation in these series, and inflation rates and (changes in) the real exchange rate, as many countries allow their currency to depreciate gradually in order to maintain competitiveness. The volatility in normal periods (equation (3)) is explained by its own past, as volatility is correlated through time- and country-specific as well as area-wide past volatility in order to account for international aspects of volatility. Consequently, once a crisis has occurred, volatility is expected to stay high temporarily, even if the probability of entering the volatile regime drops to zero. The fourth equation describing the probability of entering the volatile regime might involve a range of variables that increase the probability of a currency crisis. Variables that are found to be significant in other studies on currency crises could be included in our model via this equation. The additional expected change (ϑ_{it}, equation (5)) and volatility (δ_{it}, equation (6)) in the crisis regime are most likely driven by indicators of current inequalities, such as deviations of the real exchange rate from trend, indicators of contagion, such as the number or depth of crises in neighbouring countries, and liquidity-related variables, which influence the probability to overshoot an equilibrium value due to capital flight.

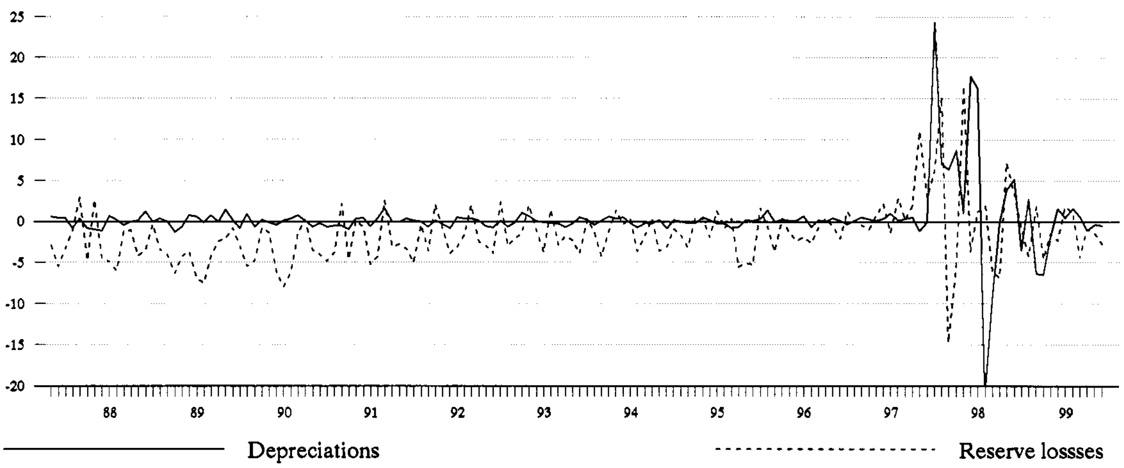
5. Results

5.1 Data

The model is estimated for a panel of monthly observations for 31 emerging or frontier markets, covering the period 1987–96. The starting point of the sample is determined by the availability of short-term debt data, whereas the end point is chosen such that the model could be evaluated out of sample for the Asian crisis. The countries included are: Argentina, Brazil, Chile, Colombia, the Czech Republic, Ecuador, Egypt, Greece, Hungary, India, Indonesia, Israel, Jordan, Korea, Malaysia, Mexico, Morocco, Pakistan, Peru, the Philippines, Poland, Portugal, Russia, Slovakia, South Africa, Sri Lanka, Taiwan, Thailand, Turkey, Venezuela and Zimbabwe. Except for Ecuador, all these countries are included in the emerging market database of the International Financial Corporation (IFC). These countries are likely to be important for international capital transactions. Two countries of the IFC database, namely China and Nigeria, are not included in our study, because of data availability problems, and because of the importance of capital restrictions in these countries. In order to avoid a predominance of high inflation periods, only observations for which inflation in the previous 12 months was less than 50% are included in our study. The effective number of observations further differs by country, and by model specification, due to data availability. Most data are from the IMF's International Financial Statistics. A detailed description of the data can be found in the Appendix.

The currency crisis index is defined as: 0.8 times the monthly percentage nominal depreciation in US dollar terms plus 0.2 times the monthly percentage decrease in international reserves. These weights are based on the volatility of both components over the entire sample of usable observations. When evaluating the model, a currency crisis will be defined as an index value above 10. Like most empirical studies on emerging markets, we do not include changes in interest rates in our crisis indicator as market interest rates are not available for many countries for a sufficient time period. Contrary to most studies, we use the same weights for depreciations and reserve losses for all countries. We prefer to use this crisis definition as optimal country-specific weights might very well change over the sample, for instance when a currency peg is abolished, or more generally after a currency crisis. This is illustrated for Thailand in Figure 1. Since the Asian crisis, the volatility of reserve changes and, especially, depreciations for the Thai baht have strongly increased. Consequently, the relative volatility of both components has changed. This problem is even more prominent if the sum of the weights differs by country, as is the case if the crisis indicator is defined in terms of the country-specific means and standard deviations of the crisis index, calculated over a pre-crisis period. These indicators signal a new crisis every few months since 1997. Moreover, objective country-specific weights are hard to obtain for currencies with a short history of low inflation, such as that of Argentina or Brazil.

Figure 1 Monthly percentage depreciations and reserve losses Thailand



As explanatory variables, a wide range of variables is considered. In the first instance, all possible candidates are included at the same time. Subsequently, variables that have the wrong sign or are insignificant are excluded. Regarding the time lag for explanatory variables, we included at least a one-month lag for (real) exchange rates, international reserves, inflation rates and the currency regime, two months for GDP, exports, imports, M2 and bank credit, and five months for international debt data. These relatively long time lags reflect the idea that economic variables become especially important if market participants become aware of them. Also, in order to be useful as early warning indicators, long time lags are necessary.

5.2 Estimation results

Table 1 shows the estimation results for the model selected for the 1987–96 period. Three numbers are given for most parameters. The first is the value of the estimated coefficient. As the model contains highly non-linear parts, this value is not always very informative. The second number is a heteroskedasticity-consistent t-value. The last number, between square brackets, gives the average change in the probability that the crisis indicator will exceed 10% if the specific variable is changed one standard deviation in the theoretically dangerous direction. This number gives some idea about the economic relevance of the variables, although it should be noted that no allowance is made for the correlation between the explanatory variables. Moreover, it only gives the average change.

Economic variables do have a significant impact on the crisis index in various ways. In the *linear part*, positive autocorrelation of reserve losses and depreciations is prominent. Moreover, domestic inflation and real overvaluation have a significant direct effect on the crisis index. This is in accordance with the assumption that most countries allow their currency to depreciate gradually, if necessary, in order to remain competitive. Autocorrelation is also important for the *variance*. A quite disturbing result is that the most important factors predicting a crisis are the recent developments in reserves and exchange rates themselves. Nevertheless, other factors matter as well. The influence on the variance of past local volatility, defined as the cross-sectional variance computed over all other countries on the same continent, can be explained by the correlation between exchange rate changes in neighbouring countries, combined with the correlation in volatility over time. Freely floating currencies have a slightly higher volatility in normal periods.

Domestic inflation, an overvalued real exchange rate and reserve losses not only have a direct (linear) effect on the crisis indicator, but they also have an impact through the *probability of entering the volatile regime*. For the probability of a crisis, defined as a crisis index of at least 10, this indirect effect dominates the direct effect. Other variables that have a significant impact on the probability are the import/export ratio, the reserves/M2 ratio, and the annual growth rate in short-term debt over reserves. Consequently, a crisis may be triggered by solvency problems (high import/export ratio or an overvalued currency) as well as liquidity-related problems. Regarding liquidity, note that over the 1987–96 sample, the reserves/M2 ratio is economically and statistically more important than the short-term debt/reserves ratio. The latter variable is, however, very important for explaining the depth of a crisis, as the *additional variance* in the crisis regime is completely dominated by this variable. This result might explain why the influence of the M2/reserves ratio is absent in Bussière and Mulder (1999), as they only investigated the depth of a crisis. The *additional expected depreciation* in the crisis regime is only limited. The only economic variable for which some influence was found is the average depreciation in neighbouring countries in the previous month. This variable reflects contagion effects in currency markets. In the absence of local depreciations in the previous month, the crisis indicator is only expected to grow by an additional 0.21 percentage points in the crisis regime. The main reason is probably that the timing of currency depreciations, or reserve losses, is not easily predictable, otherwise market participants could make arbitrage profits. The influence of uncertainty is much more important.

In order to investigate parameter stability, the same model that was selected for our 1987–96 sample was also estimated for our full sample (May 1987–June 1999), and for the most recent period only (1997–99). Unfortunately, most parameters are not stable. The most notable changes concern the probability of entering the crisis regime. The liquidity-related variables have become much more

Table 1

Estimation results for optimal specification over 1987–96

Estimation sample	1987–96	1987–99	1997–99
$X1_{it}$: *linear expectation*			
Intercept	–1.26 (2.7)	–1.93 (4.2)	–2.81 (2.7)
Quarterly depreciation	0.112 (6.9) [0.22]	0.109 (7.6) [0.23]	0.069 (2.8) [0.32]
Quarterly growth in reserves	–0.011 (3.5) [0.12]	–0.014 (4.5) [0.15]	–0.019 (2.8) [0.18]
Domestic annual inflation	0.015 (3.2) [0.06]	0.013 (3.0) [0.06]	0.019 (1.7) [0.09]
Real exchange rate	0.22 (2.1) [0.02]	0.39 (3.8) [0.03]	0.63 (1.7) [0.08]
$X2_{it}$: *normal variance*			
Intercept	0.28 (3.2)	0.32 (3.2)	0.95 (2.3)
Floating rates	0.51 (1.4)	0.04 (0.1)	0.00 (0.0)
Exchange rate volatility (6 months weighted)	9.45 (4.5) [1.52]	11.70 (6.9) [2.22]	10.45 (5.0) [8.41]
Reserves volatility (6 months weighted)	0.60 (3.9) [2.47]	0.58 (5.2) [2.37]	0.29 (1.9) [0.17]
Average local exchange rate volatility (3mw)	1.17 (2.0) [0.02]	0.44 (0.9) [0.01]	0.00 (0.0) [0.00]
$X3_{it}$: *crisis regime probability*			
Intercept	–9.00 (3.0)	–6.57 (2.2)	–1.19 (0.2)
Real exchange rate	1.42 (2.1) [0.30]	0.99 (1.6) [0.26]	0.35 (0.2) [0.16]
Domestic annual inflation	2.84 (2.2) [0.31]	2.07 (1.9) [0.28]	1.80 (0.6) [0.31]
Import/export ratio	0.62 (3.0) [0.34]	0.25 (1.2) [0.17]	–1.67 (2.4) [–1.03]
Weighted quarterly growth in reserves	–0.86 (2.0) [0.50]	–0.82 (2.5) [0.62]	–0.37 (0.8) [0.27]
Annual growth short-term debt over reserves	0.43 (1.8) [0.24]	0.55 (2.5) [0.40]	1.61 (3.9) [1.74]
Reserves/M2 ratio	–3.50 (2.8) [0.70]	–3.07 (3.0) [0.78]	–4.41 (1.9) [1.71]
$X4_{it}$: *crisis regime additional expectation*			
Intercept	0.21 (0.5)	0.78 (1.6)	2.55 (1.6)
Local average monthly depreciation	0.38 (1.6) [0.18]	0.35 (1.5) [0.18]	0.31 (0.9) [0.38]
$X5_{it}$: *crisis regime additional variance*			
Intercept	0.00 (0.0)	0.00 (0.0)	3.33 (0.4)
Short-term debt/reserves ratio	35.99 (2.1) [1.17]	46.82 (2.7) [1.19]	79.67 (1.6) [0.69]
Number of observations	2,557	3,312	755

Note: Heteroskedasticity-consistent absolute t-values in parentheses. Between square brackets, the increase, measured in percentage points, in the probability of obtaining a crisis indicator value of at least 10, due to a one standard deviation change in the explanatory variable, evaluated over the 1987–96 sample, is shown.

important over the recent period, whereas the influence of solvency-related variables has declined. The import/export ratio in particular changes dramatically, and even becomes significantly negative over the 1997–99 period. The influence of the real exchange rate and inflation also decline, but these effects are somewhat compensated for by a higher direct effect of these variables. Regarding the liquidity variables, the influence of the growth rate of short-term debt to reserves is highly significant. The reserves/M2 ratio also remains significant, however.

Somewhat surprisingly, the influence of contagion seems to have declined over the latter period. Whereas the influence of local depreciations on the additional expected depreciation in the crisis regime has hardly changed, the influence of past local volatility on the variance has declined. Given the worldwide effects of the Asian and Russian crises, this result seems counter-intuitive. One reason for this result might be that, more recently, contagious effects have materialised quicker, that is to say within one month. If that were the case, contagion would not show up in the influence of past depreciations in neighbouring countries, but in the depreciation of the domestic currency. Indeed, the influence of own past exchange rate volatility has increased. In order to investigate the possibility that contemporaneous correlations have increased recently, covariance matrices of normalised residuals of our model were calculated, based on a one-year moving window.[7] Only 12 countries are used for this

[7] The normalised residuals are computed by means of the cumulative distribution function. For each residual, the probability of finding a smaller value than the one observed is calculated. Subsequently, the corresponding normalised

purpose, as data for the other countries were lacking, or excluded because of excessive inflation. Figure 2 shows the cumulative explanatory power of the first three principal components based on these covariance matrices. About 75% of the variance of those 12 crisis indicators can be explained by three common factors. Although the explanatory power of the first three principal components has increased somewhat in recent years, the current level is comparable to the levels of the early 1990s. Therefore, we do not find convincing evidence of increased contagion, other than what can be explained by the variables in our model, over recent years.

Figure 2 Cumulative expanatory power first three principal components nomalised model residuals

5.3 Crisis prediction

Despite the fact that the optimal model for 1987–96 differs from that for 1997–99, it is interesting to see to what extent the model estimated for 1987–96 can be used to predict exchange rate crises in the years thereafter. For that purpose, a currency crisis is defined as a value on the currency crisis indicator of at least 10%. So defined, our sample contains 49 currency crises: 25 before 1997 and 24 thereafter. The total number of crises over the sample for the 31 countries included in the study is somewhat higher, but we only analyse crisis for which we have data on both the indicator and the explanatory variables, and for which inflation over the previous 12 months was less than 50%.

Table 2 shows the predictive power of our model. Success in predicting crises naturally depends on the threshold used to select vulnerable observations. Within sample, if the threshold level is set at 10%, meaning that a warning signal is given whenever the probability of a crisis is at least 10%, 10 out of 25 crises are detected. This comes at the expense of also selecting 111 quiet periods out of 2,532. The large number of tranquil periods selected should not come as a surprise, as our model predicts that the probability of selecting a tranquil period is up to 90%. Indeed, one should not expect to be able to select crisis observations without signalling tranquil periods as well, since this would lead to arbitrage opportunities. If the threshold is lowered to 1%, 23 out of 25 crisis observations are selected, but also about 37% of tranquil periods. At the 0.2% level, all crises are selected. The higher the threshold, the more selective the model. This is reflected in the noise-to-signal ratio, which rises from 11.0% to 65.1% when the threshold is lowered from 10% to 0.2%.

Although the noise-to-signal ratio of our model seems good, one may wonder whether the model is really informative or simply providing information that is already known. More precisely, given the importance of past depreciations and reserve losses in our model, some of the crises we signal are simply continuations of a crisis in the previous period. In order to detect the importance of these repeated crises, we also calculated the predictive power for a restricted sample, where observations for a country are excluded up to two months after a crisis in that country. These results are shown on the

---

residual is computed by means of the inverse of the standard normal cumulative distribution function (Palm and Vlaar, (1997)). This normalisation procedure has the advantage that the influence of outliers is reduced.

right-hand half of Table 2. Within sample, four crises were continuations of previous ones, and all four are detected at the 10% threshold. However, as 34 out of 39 non-crisis observations that followed a crisis were also signalled as a crisis at the 10% threshold, the noise-to-signal ratios are hardly affected by the truncation.

Table 2
Predictive power crisis index model

	All observations			Excluding 2 months after crisis		
	Crises	Tranquil	Noise/signal	Crises	Tranquil	Noise/signal
	Within sample: May 1987 – December 1996					
Total	25	2532		21	2493	
P10% > 10%	10	111	0.110	6	77	0.108
p10% > 5%	14	308	0.217	10	270	0.227
p10% > 2%	21	608	0.286	17	569	0.282
p10% > 1%	23	913	0.392	19	874	0.387
P10% > 0.5%	24	1315	0.541	20	1276	0.537
P10% > 0.2%	25	1649	0.651	21	1610	0.646
	Out of sample: January 1997 – June 1999					
Total	24	731		16	704	
P10% > 10%	13	39	0.098	5	18	0.082
p10% > 5%	14	73	0.171	6	49	0.186
p10% > 2%	17	151	0.292	9	124	0.313
p10% > 1%	21	227	0.355	13	200	0.350
P10% > 0.5%	23	345	0.492	15	318	0.482
P10% > 0.2%	24	454	0.621	16	427	0.607

Note: The noise-to-signal ratio is defined as the number of bad signals as a share of possible bad signals, divided by the number of good signals as a share of possible good signals.

Out of sample, the results are about as good as within sample. Most of the noise-to-signal ratios are even slightly lower out of sample. Apparently, the fact that not all model parameters are stable over the sample does not affect the predictive power very much. The number of repeated crises is much higher in the forecast period. As in the estimation period, these are all predicted at the 10% threshold level. All in all, the results seem reasonable. At the 1% threshold level 87.5% of crises are detected, at the cost of signalling 33% of the time.

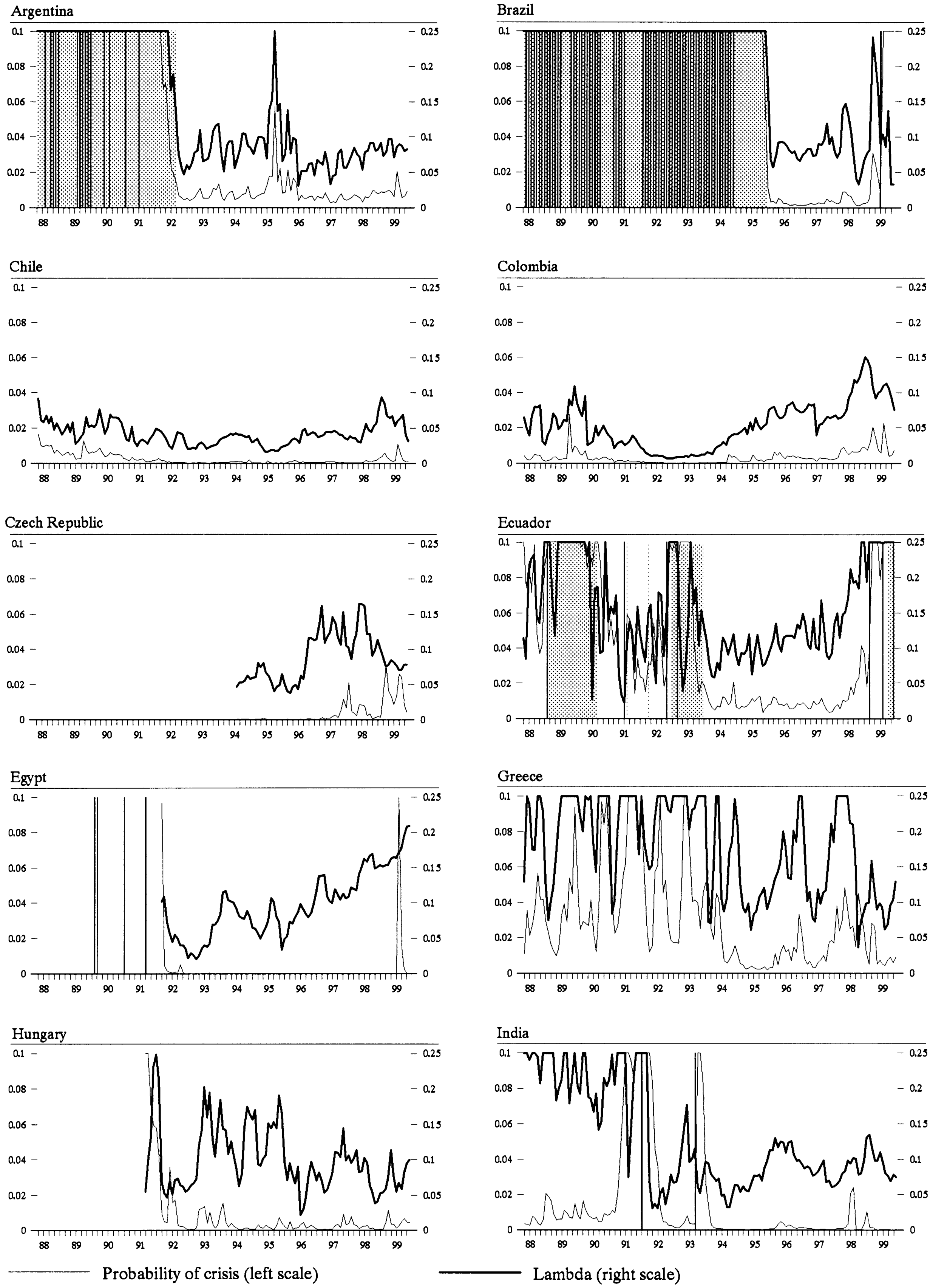
In order to give a better idea of which crises are predicted, Table 3 provides the complete list of crises included in the study. The crises that are best predicted are of course those that immediately followed other crises. Most of the major first crises are detected only at the 1% level. The probability of a crisis in Thailand in July 1997 was only 1.3%, and 1.0% in Russia in August 1998. The Mexican crisis is predicted at the 4.7% level if December 1994 is taken as the crisis date. If the start of this crisis is located at November, during which the crisis indicator was 5.9, the probability of a crisis is 1.4%. The one major crisis that is missed at the 1% level is the recent one in Brazil, for which the probability according to our model was only 0.8%. This is all the more surprising because this was probably the best anticipated crisis ever. One reason for the relatively poor performance of the model for this crisis is the fact that Brazil had increased its foreign reserves in December 1998 by 8.5%. Consequently, the probability of crisis was sharply reduced. Another reason is that the real exchange rate was hardly giving any sign of overvaluation, due to the fact that it was even slightly more overvalued during the reference period (1990). This example clearly shows the advantage of including real appreciation over a fixed period, instead of the level of the real exchange rate. However, as we have shown, we could not find empirical support for that formulation.

Table 3
Characteristics of the currency crises in our sample

Date	Country	Crisis index	Probability of crisis	λ	Annual inflation
8801	Jordan	11.4	3.07	13.4	–1.8
8802	Poland	14.6	5.13	24.6	46.7
8804	Jordan	14.7	22.62	82.3	1.7
8806	Jordan	15.0	32.05	86.1	0.3
8903	Venezuela	121.7	9.01	53.9	43.5
9010	Pakistan	13.3	4.59	27.5	10.6
9101	Ecuador	10.4	0.92	2.3	49.5
9103	Portugal	11.1	2.08	14.9	12.9
9103	Zimbabwe	12.5	2.71	6.7	18.8
9106	Zimbabwe	13.3	19.59	49.0	22.2
9107	India	13.6	17.24	65.3	13.0
9109	Zimbabwe	17.8	35.32	0.0	22.0
9205	Ecuador	11.0	2.69	15.6	49.6
9301	Zimbabwe	12.9	10.82	24.9	46.3
9303	India	11.1	0.33	11.5	5.7
9307	Pakistan	13.9	15.15	61.8	9.6
9309	Pakistan	11.5	20.50	3.4	9.8
9401	Zimbabwe	11.3	1.14	5.7	18.6
9405	Venezuela	35.7	1.38	18.7	48.1
9412	Mexico	53.7	4.69	30.6	6.9
9501	Mexico	11.4	42.21	78.0	7.1
9503	Mexico	18.9	40.38	4.3	14.3
9510	Mexico	11.7	3.11	10.6	43.5
9604	South Africa	14.9	8.14	28.2	6.3
9610	Pakistan	15.7	9.14	45.2	9.8
9707	Philippines	10.8	0.69	19.0	5.7
9707	Thailand	20.7	1.33	14.5	4.4
9708	Indonesia	14.4	1.53	8.3	5.4
9709	Zimbabwe	12.9	10.55	48.1	18.0
9710	Indonesia	11.6	16.63	6.3	7.3
9711	Korea	20.5	2.26	9.9	4.2
9711	Zimbabwe	19.7	12.51	38.4	16.0
9712	Indonesia	23.6	12.16	7.8	8.8
9712	Korea	39.8	20.85	14.8	4.3
9712	Philippines	15.0	5.82	15.8	7.5
9712	Thailand	13.5	11.93	9.6	7.6
9801	Indonesia	96.6	32.55	6.0	10.3
9801	Malaysia	14.9	10.89	7.9	2.9
9801	Thailand	13.2	21.55	6.4	7.6
9805	Indonesia	30.7	25.54	5.7	42.5
9806	Indonesia	33.5	34.73	2.5	49.7
9806	Pakistan	10.3	3.31	15.9	5.6
9806	South Africa	13.5	1.89	11.1	5.1
9808	Mexico	10.6	0.49	7.5	15.4
9808	Russia	29.5	1.01	7.9	5.6
9809	Ecuador	14.0	3.85	28.0	34.2
9809	Russia	81.0	30.36	38.6	9.5
9901	Brazil	55.2	0.82	9.1	1.7
9902	Ecuador	25.0	10.37	24.9	42.3

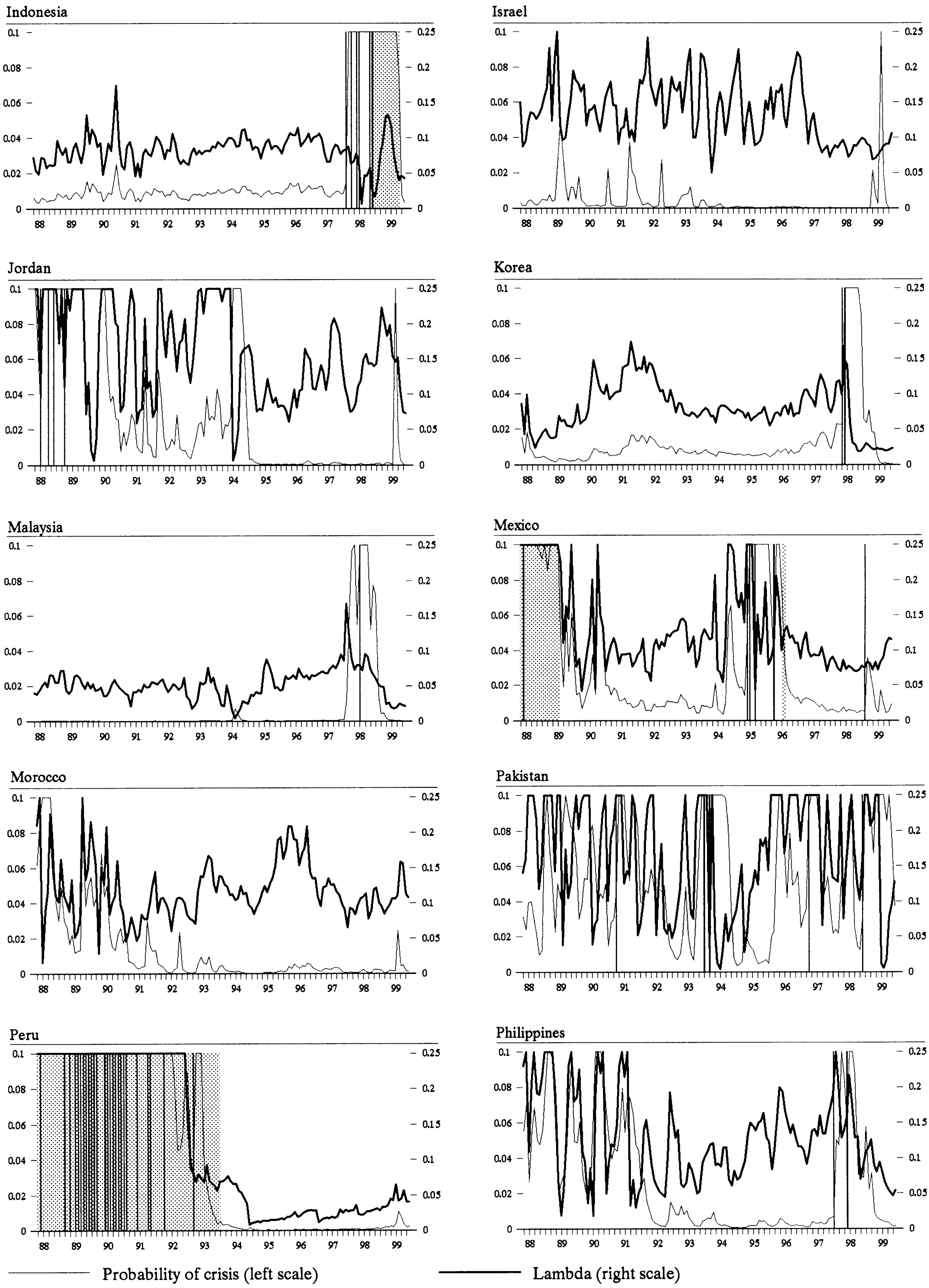
Note: λ represents the probability of entering the crisis regime of our model. Annual inflation denotes the inflation rate over the 12 months before the crisis.

Figure 3 Crisis indicators for various countries



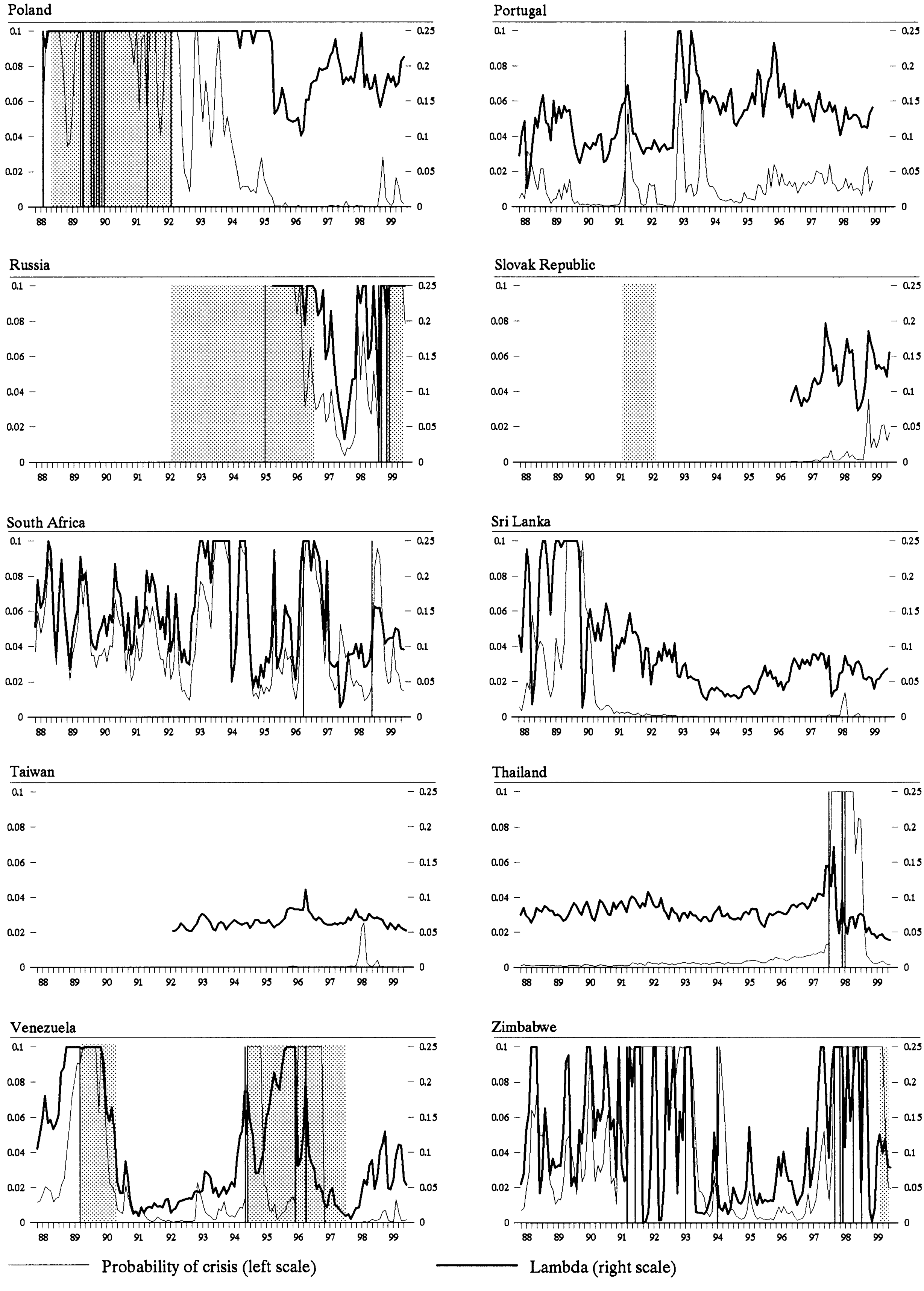
Note: Bars denote crises; Shaded areas depict periods with inflation higher than 50% annually.

Figure 3 Crisis indicators for various countries (continued)



Note: Bars denote crises; Shaded areas depict periods with inflation higher than 50% annually.

Figure 3 Crisis indicators for various countries (continued)



Note: Bars denote crises; Shaded areas depict periods with inflation higher than 50% annually.

Apart from the probability of crisis, which incorporates all elements of our model, Table 3 also shows the probability of entering the crisis regime (λ). The main reason for showing both is that the probability of crisis is dominated by current volatility, whereas λ signals vulnerabilities due to economic conditions. Consequently, this crisis indicator might be better suited to signalling first crises. Once a currency is in crisis, λ is likely to fall as the real exchange rate, and possibly the trade balance, improve. Despite this lower λ the probability of crisis will remain high due to the lagged volatility effect. The average value of λ over the estimation sample turned out to be 12.7%. During most crises, λ was much higher. However, even for some of the first crises, for instance the one in Brazil in January 1999, it was lower than the average value. This is probably due to country-specific effects, for instance an overvalued real exchange rate in 1990, the relative importance of trade for the current account, or differences in measurement.

In order to allow country-specific differences to be visualised, and to enable us to say something about the lead time of these indicators, Figure 3 shows both the probability of crisis and λ for the countries included in this study.[8] For most first crisis episodes, λ rose in the years before the crisis. Clear examples of this are Malaysia, Thailand and the Philippines, and to a lesser extent Korea during the Asian crisis, Mexico before the 1994 crisis, Ecuador before 1998 and Venezuela before 1989 and 1994. The level of λ is less informative, as there are clear differences between countries. Once the crisis has erupted, the probability of further crises strongly increases, whereas λ is reduced. In view of these results, the predictive properties shown in Table 2 can probably be improved if (changes in) λ are taken into account as well.

Finally, what does our model say about the next crisis? In the light of the developments in λ, the clearest example of increased vulnerability is probably given for Egypt. Indeed, rumours about a forthcoming devaluation of the Egyptian pound are widespread. Furthermore, several Latin American countries (Ecuador, Colombia, Peru, Venezuela and possibly Argentina) are clearly vulnerable, whereas the Asian countries seem to have stabilised.

6. Conclusion

In this paper, a new method is introduced to predict currency crises. The method models a monthly continuous crisis index, based on depreciations and reserve losses, using observations of both crisis periods and quiet periods. The fact that during currency crises the behaviour of market participants differs from under normal circumstances is studied using an econometric model with two regimes, one for troubled, volatile episodes, and one for normal periods. The model is capable of separating the variables that influence the probability of a currency crisis from those that have an impact on the depth of a crisis. In our model, the probability of crisis is directly related to the probability of entering the volatile regime. Relevant variables turn out to be the real exchange rate, the inflation rate, the growth of the short-term debt/reserves ratio, growth in reserves, the reserves/M2 ratio and the import/export ratio. Variables influencing the depth of a crisis have, in our model, a significant impact on the extra expected depreciation and extra volatility in the crisis regime. Local depreciations and the short-term debt/reserves ratio turn out to be the crucial variables here. The most important factors for explaining the current month's crisis index are, however, recent changes in the exchange rates and reserves themselves.

Several differences are noticeable, when comparing results for 1987–96 with those for 1997–99. The main difference between the two periods is that the short-term debt/reserves ratio has become much more important lately, whereas the import/export ratio seems to have lost its explanatory power. This indicates that recent crises were probably more liquidity-driven than previous ones. No clear evidence is found for increased contagion effects. The influence of local depreciations in previous months

[8] Turkey is not included as the its annual inflation rate was below 50% only before 1988. Missing values for economic variables included in the model were replaced with last known values in order to avoid discontinuous lines. The probability of crisis and λ are bounded from above at 10% and 25% respectively.

seems to have declined somewhat, whereas the contemporaneous correlations of the normalised residuals of our model rose only slightly. This result seems surprising given the worldwide impact of the Asian crisis. However, the domino effects of this crisis, as well as the large impact on the world economy, might also be explained by the fact that these countries are much more open and more developed than most previous targets of currency attacks. Consequently, large initial depreciations immediately affected the economic growth potential for neighbouring countries, as they were competing to a large extent on the same markets, and relied on exports for their growth.

The model is reasonably successful in predicting currency crises, including out of sample. If the threshold above which the model gives a warning signal for an impending crisis is set at 1%, 21 out of 24 crises are predicted out of sample. However, this comes at the cost of also giving a warning signal 35% of the time when no crisis is about to occur. The clearest signals are provided for crises that followed other crises. First crises are better detected by changes in the probability of entering the crisis regime (λ). These provide a good summary of changes in the economic vulnerability of currencies. As the link between vulnerabilities and currency crises is far from perfect, however, one cannot expect to detect all currency crises with the help of just one econometric model.

Appendix: Data sources

General: The countries included in this study are: Argentina, Brazil, Chile, Colombia, the Czech Republic, Ecuador, Egypt, Greece, Hungary, India, Indonesia, Israel, Jordan, Korea, Malaysia, Mexico, Morocco, Pakistan, Peru, the Philippines, Poland, Portugal, Russia, Slovakia, South Africa, Sri Lanka, Taiwan, Thailand, Turkey, Venezuela and Zimbabwe. The database consists of monthly observations for the period January 1970 to June 1999. Observations for countries with an annual inflation rate above 50% in the previous month are excluded from the estimation and evaluation procedures. Most data come from the August 1999 International Financial Statistics CD-ROM of the IMF. Additional data are from Datastream or taken from the internet. For Taiwan, which is not an IMF member, most data come from the Directorate General of Budgeting and Accounting Statistics (DGBAS). All explanatory variables are lagged at least one month, and more if the publication lag of the data is likely to be longer. In order to limit the influence of large reserve changes or nominal exchange rates, explanatory variables involving these two variables are bounded to their mean plus or minus five standard deviations. Local variables are calculated over usable observations of the included countries per continent (Asia, Latin America, Europe, or Africa plus the Middle East), excluding the country concerned. Global variables are calculated over the usable observations of all included countries, again excluding the country concerned. Whenever a weighted average of variable X over i months is used, it is calculated as:

$$X_{Wi} = \sum_{j=0}^{i-1}(i-j)X_{t-j} / \sum_{j=1}^{i} j \, .$$

Exchange rates: line ae of the IFS, end-of-period local currency per US dollar, except for Taiwan (London exchange market). As explanatory variable, the variable is lagged in our model at least one month.

International reserves: line 1..ld of the IFS, international reserves excluding gold in millions of US dollars, except for South Africa, for which total reserves including gold (line 1..sf) are used. For Taiwan, official reserves in US dollars, provided by DGBAS. As explanatory variable, the variable is lagged in our model at least one month.

Currency crisis index: 0.8 * monthly percentage depreciation + 0.2 * monthly percentage reserve losses. In the estimation process, this variable is bounded at 50%, in order to limit the influence of an extreme observation (Venezuela, March 1989).

Consumer price index: line 64 of the IFS. For Taiwan, the urban CPI provided by DGBAS is used. As explanatory variable, the variable is lagged in our model at least one month.

Real exchange rates: CPI-based trade-weighted real exchange rates. Three different sources are used: the measure of JP Morgan for Argentina, Brazil, Chile, Colombia, Ecuador, Greece, India, Indonesia, Korea, Malaysia, Mexico, Morocco, Pakistan, Peru, the Philippines, South Africa, Taiwan, Thailand, Turkey and Venezuela; the IFS measure (line rece) for Hungary, Israel, Poland, Portugal, Russia and Slovakia; and own calculations based on trade weights with Japan, the European Union and the United States for the Czech Republic, Egypt, Jordan, Sri Lanka and Zimbabwe. For our own calculations, period average US dollar exchange rates (line af of IFS) and CPIs of Japan, Germany, the United States and the countries concerned are used. The trade weights are from various issues of the Direction of Trade Statistics. As explanatory variable, the variable is lagged in our model at least one month.

M2: Sum of lines 34 and 35 of the IFS. For Hungary, monthly observations provided by the National Bank of Hungary are used. For Taiwan, monthly figures are from DGBAS. As explanatory variable, the variable is lagged in our model at least two months.

Credit: line 32d of the IFS, domestic credit to private sector. For Taiwan, domestic credit to private sector collected by DGBAS; for Hungary, monthly consumer credit from the National Bank of Hungary. As explanatory variable, the variable is lagged in our model at least two months.

Short-term foreign debt and total foreign debt: BIS database. Semiannual reports of foreign lending of BIS reporting banks by country and remaining maturity. Short-term debt is defined as debt with a remaining maturity of less than one year. As explanatory variables, these variables are lagged in our model at least five months as there is a five-month publication lag. This means using the end-December positions for the months May to October of the next year, and the end-June positions for the months November to April.

Exports and imports: lines 70..d and 71..d of the IFS, exports and imports in millions of US dollars. As explanatory variables, the variables are lagged in our model at least two months.

Gross domestic product: line 99b of the IFS, GDP in current prices. This quarterly series is transformed into a monthly series, using CPI and industrial production (line 66 of the IFS) as indicators. The quarterly GDP series for Taiwan is from DGBAS. If the IFS database did not provide monthly industrial production series, other sources were used as well. The alternative sources for industrial production are: OECD (Hungary, Poland, Portugal and Russia), Macroeconomica (Argentina), Lopes Filho & Associates (Brazil), National Statistical Service of Greece, Biro Pusat Statistik (Indonesia), Statistics South Africa, DGBAS (Taiwan), Bank of Thailand, State Institute of Statistics (Turkey) and Veneconomia (Venezuela). As explanatory variable, the variable is lagged in our model at least two months.

Exchange rate regime: Annual report on exchange arrangements and exchange restrictions, IMF, various issues.

Bibliography

Berg, A and C Pattillo (1998): "Are Currency Crises Predictable? A Test". *IMF Working Paper*, 98/154.

Borenzstein, E, A Berg, G-M Millesi-Ferretti and C Pattillo (1999): "Anticipating Balance of Payments Crises – The Role of Early Warning Systems". *IMF Occasional Paper*, forthcoming.

Bussière, M and C Mulder (1999): "External Vulnerability in Emerging Market Economies: How High Liquidity Can Offset Weak Fundamentals and the Effects of Contagion". *IMF Working Paper*, 99/88.

Calvo, G (1998): "Varieties of Capital-Market Crises", in Calvo, G and M King (eds.) *The debt burden and its consequences for monetary policy*. IEA Conference Volume, No. 118. New York: St. Martin's Press; London: Macmillan Press; in association with the International Economic Association.

Chang, R and A Velasco (1998): "Financial Fragility and the Exchange Rate Regime". *NBER Working Paper*, 6469.

Frankel, J A and A K Rose (1996): "Currency Crashes in Emerging Markets: An Empirical Treatement". *Journal of International Economics*, 41, pp. 351-66.

Glick, R and A K Rose (1998): "Contagion and Trade: Why are Currency Crises Regional?" *NBER Working Paper*, 6806.

Kaminsky, G L, S Lizondo and C M Reinhart (1998): "Leading Indicators of Currency Crises". *IMF Staff Papers*, 45, pp. 1-48.

Kaminsky, G L and C M Reinhart (1996): "The Twin Crises: The Causes of Banking and Balance-of-Payments Problems". *International Finance Discussion Papers*, 544, Board of Governors of the Federal Reserve System.

Krugman, P (1979): "A Model of Balance-of-Payments Crises". *Journal of Money, Credit and Banking*, 11, pp. 311-25.

JP Morgan (1998): "Event Risk Indicator Handbook". JP Morgan, London (can be downloaded from: www.jpmorgan.com).

Obstfeld, M (1986): "Rational and Self-Fulfilling Balance-of-Payments Crises". *American Economic Review*, 76, pp. 72-80.

Obstfeld, M (1995): "The Logic of Currency Crises", in Eichengreen, B, J Frieden and J von Hagen (eds.) *Monetary and fiscal policy in an integrated Europe. European and Transatlantic Studies*, Heidelberg; New York and London: Springer, pp. 62-90.

Palm, F C and P J G Vlaar (1997): "Simple Diagnostic Procedures for Modelling Financial Time Series". *Allgemeines Statistisches Archiv*, 81, pp. 85-101.

Sachs, J D, A Tornell and A Velasco (1996): "Financial Crises in Emerging Markets: The Lessons from 1995". *Brookings Papers on Economic Activity*, pp. 147-98.

Tornell, A (1999): "Common Fundamentals in the Tequila and Asian Crises". *NBER Working Paper*, 7139.

Velasco, A (1987): "Financial Crises and Balance-of-Payments Crises". *Journal of Development Economics*, 27, pp. 263-83.

Vlaar, P J G (1998): "Target Zones and Realignment Risk: An Integrated Approach". *De Economist*, 146, pp. 91-116.

How global are global financial markets? The impact of country risk

Dominik Egli[1]

1. Introduction

Financial transactions are costly. On the one hand, processing a transaction requires resources, on the other hand the regulatory framework is costly as well. In both areas there have been dramatic changes recently. Computerisation and advances in telecommunications lead to considerably lower technical costs. Furthermore, deregulation has eliminated many barriers to trade. Financial markets have become and still are in the process of becoming more open, and one often hears of the “globalisation of financial markets”. As already mentioned in the title, I will investigate the question of what this means in geographical terms. International transactions which lead to a net debtor position of countries result in an additional type of transaction cost: country risk. Unlike domestic borrowers, sovereign countries cannot be forced to perform their contracts by legal action against them. Instead, creditors have to rely on indirect mechanisms. In the following, I describe the consequences of country risk in detail and discuss the main mechanism for dealing with it. It will become clear that country risk is the main transaction cost for countries which should actually be large debtors given the potential of their economies. Country risk, therefore, considerably hampers the globalisation of financial markets.

2. Country risk

A creditor-debtor relationship typically consists of three types of actions. At the beginning of the relationship, the creditor lends money to the debtor. At the end, the debtor pays back the money lent. In between, the debtor pays interest on the loan. How much money has to flow on which date is usually written into a contract. The strategic situation is as simple as it is explosive: whereas the creditor would like to get back as much as possible, the debtor prefers to pay back as little as possible.

Basically, payments are voluntary. Depending on the legal system, a damaged party has several means by which to impose sanctions on the defaulting party. When payments become due, a debtor weighs the costs of honouring the contract against the costs of defaulting on the loan. A simple model might clarify the situation. On one side there is a debtor, on the other side there are many potential lenders. Let us assume that each lender is very wealthy.[2] In this type of scenario, we can analyse the situation of a lender and a debtor in which the debtor has all the bargaining power. By combining interest payments and repayment of principle, we have a two-stage strategic game. First, a contract (D, r) is signed, where D is the amount the lender hands over to the debtor and r is the interest rate. D then goes to the debtor. Subsequently, repayment $S = (1 + r) D$ becomes due. If the debtor does not pay back S, sanctions can be imposed on him, which cost him P, an exogenous amount. The debtor’s decision is now simple: if $S < P$ he honours the debt, if $S > P$ he defaults, and if $S = P$ he is indifferent (we assume that he honours the debt in this case). When negotiating the contract at the first stage, the parties anticipate the debtor’s decision rule. Since there is no other risk than default risk, the debtor only signs a contract with $r^* = i$, where i is the world market interest rate. According to the debtor’s decision in the second stage, the maximum repayment the debtor is willing to make is P. The

---

1 I would like to thank Bernhard Emunds for valuable suggestions. The views expressed in this article are those of the author and should not be interpreted as reflecting those of the Swiss National Bank or other members of its staff.

2 Alternatively, we could assume that the lenders can form lending syndicates without incurring any expenses.

maximum money flow $\overline{D}$ the lender is willing to lend is computed from the condition $P = (1 + i)\,D$, leading to $\overline{D} = P/(1 + i)$ (Eaton et al. (1986)).

It is worth mentioning that this result applies to both domestic and international debt contracts. In the domestic area, the sanctioning costs P consist of costs the debtor incurs from bankruptcy. In bankruptcy proceedings, the receiver seizes the tangible assets of the debtor. If the debtor has to bear a positive share of the costs of the bankruptcy proceedings, he only defaults if he is unable to pay.[3] Nonetheless, the willingness to pay is the driving force. Faced with the threat of bankruptcy, the debtor is willing to pay whenever he is able to do so. At the international level, the willingness to pay is also the driving force. Since it is much more difficult to enforce performance of a contract through bankruptcy proceedings, however, this fact is more apparent than at the domestic level.

In the absence of bankruptcy proceedings, the maximum debt amount is not determined by the profitability of the project the debtor wants to carry out with the funds lent, but by the sanctioning costs P. The lender is willing to lend any amount up to $\overline{D}$. This can lead to credit rationing (Allen (1983)). In this case, the debtor would benefit from higher sanctioning costs. For each additional dollar of sanctioning costs, he gets $1/(1 + i)$ additional dollars of debt D. The lender does not care how the debtor uses the money he gets, as long as the use does not influence the sanctioning costs P.

In sum, it can be said that the costs sanctions impose on the debtor determine the maximum amount of debt. The severity of the bankruptcy threat as the main penalty in the domestic realm causes the willingness and the ability to repay to coincide. There are, however, no international bankruptcy proceedings. This constitutes the main difference between domestic and international debt contracts. In order to analyse the determinants of international debt, we have to take a closer look at the sanctions lenders can impose on defaulting international debtors.

3. The costs of sanctions

In what follows, I will present and discuss sanctions and their costs. There are two main types of sanctions. In the vernacular, there are two approaches to induce a certain behaviour, referred to as "carrot and stick". This approach can easily be applied to sanctions. Under the "carrot" approach, a lender threatens to exclude the debtor from future access to international financial markets, and under the "stick" approach, a lender threatens to impose direct sanctions. Exclusion from international markets leads to costs in the future, while direct sanctions lead to immediate costs.

3.1 Access to international financial markets

In the two-stage game of the previous section, market access cannot act as a disciplining device since the game ends after the repayment decision of the debtor. If the two-stage game is repeated "many" times, two incentives to preserve market access arise. First, credits can be used to smooth consumption in case of income fluctuations. In bad times, the country imports more than it exports, thereby getting into debt, and in good times it repays by running a trade surplus. Second, credits can be used to finance profitable projects. I will start with the latter.

3.1.1 Investment

In the public discussion, investment are probably the most prominent reason for international debt. A transfer of savings from rich countries to poor countries will enable the latter to finance projects and thereby grow. The proceeds of the project will allow the debtor country to repay its debt and still keep something for itself. Under the threat of being denied access to international financial markets, the

[3] In cases where the receiver is not able to seize all assets or the debtor is able to "take the money and run", default can occur even though the debtor would be able to honour the contract.

country repays in order to receive international funds to finance additional projects in the future. International lending for financing investments takes place when the return on investment is higher abroad than at home. As long as this is the case, the debtor country has no reason to prove its honesty since the creditors will grant additional loans out of profit considerations. This reasoning no longer makes sense when the investment prospects are the same in both countries. If this point is reached, however, firms in the debtor country no longer need access to international markets since they can finance their projects on the home market at equal cost. Therefore, the threat of an exclusion from international financial markets has no bite. Sooner or later, the debtor country will no longer need access to international markets to finance valuable projects. Anticipating this, rational creditors are not willing to lend at all. From the debtor countries' point of view, the worst possible situation becomes a reality.

The models of Kletzer (1984) and Cole and English (1991) show two possible ways to handle this problem. Basically, in both papers the existence of a last period, which triggers the backward inducement argument used above, is assumed away. Kletzer (1984) assumes that projects financed by foreign lending enhance productivity, but only for one period. These productivity gains are lost in the event of exclusion from the international financial markets. Cole and English (1991) model an economy with a growing amount of infinitely living individuals. They assume that international transfers are necessary to guarantee optimal per capita consumption. A default triggers exclusion from the international financial markets and leads to a decline of per capita consumption. This threat makes international lending possible.

3.1.2 Consumption smoothing

Instead of financing projects, international credits can be used for consumption smoothing. The international capital markets work as an insurance against income fluctuations. Income fluctuations can be triggered by crop fluctuations or by changes in the terms of trade. If income is uncertain for each period and the country prefers stable consumption to unstable consumption, it must always allow for the possibility of using international credits in the future. As Eaton and Gersovitz (1981) show, the threat of being cut off from receiving additional funds is enough to explain international debt. In good times, the debtor country honours its obligations voluntarily in order to receive financing in bad times. Bulow and Rogoff (1989b) question the conclusion of Eaton and Gersovitz. They point out that a country has other possibilities to perform consumption smoothing. The debtor country may just as easily pay in advance for state-contingent future payments by international investors. The country thereby signs an insurance contract. The premium is paid in advance, and the contract designates payments in the case of unfavourable events in the future. According to Bulow and Rogoff (1989b), in equilibrium loans should not be granted, since the country would strictly profit from a switch from a credit contract to an insurance contract. Potential insurers have no incentives not to accept a contract since they get paid in advance. In this case, the threat of exclusion from the international financial markets is not enough to discipline a sovereign debtor.

3.2 Direct sanctions

3.2.1 Bankruptcy

Of course, a lender always has the possibility to sue a defaulting foreign debtor. The debtor then risks losing his assets. However, governments have several options to prevent the threat of seizing their assets taking effect. For instance, a government can restrict the access of foreigners to bankruptcy proceedings. It can also directly change the bankruptcy procedure such that it becomes too costly. Quite a different possibility is to restrict capital mobility. Winning a lawsuit is of limited value if the lender is not allowed to export the proceeds. Yet another possibility is to add an official provision to guarantee the debt contract and to forbid payments. A government which is unwilling to repay a loan always has means to undermine the credibility of the bankruptcy proceedings (Niehans (1986)).

3.2.2 Confiscation of foreign assets

The lenders can threaten to seize the foreign assets of a defaulting debtor country. In order for this threat to have an impact, there have to be clearly assignable assets. In addition, these assets need to be in the country in case a default occurs. This means that confiscation is only a threat to the country if it is not able to repatriate the assets in time. Moreover, lenders need the cooperation of their government or jurisdiction. According to Bulow and Rogoff (1989a), the law of most lender countries permits the seizure of foreign assets in order to satisfy domestic lenders.

3.2.3 Trade credits

Banks usually act as intermediaries for international transactions. In this way, delivery and payment need not coincide perfectly. Denying trade credits increases the cost of international trade since the debtor country now has to build up reserves in order to pay instantly for imported goods.

3.2.4 Trade sanctions

Lenders can impose a trade embargo. Such an embargo only works if all trading partners cooperate. Since the debtor country is still interested in international trade, an embargo leads to losses by the foreign exporters. Since exporters usually are not lenders, the losers and the winners are not the same. Therefore, the losers have to be paid. If they are not, they participate in the political process to have the embargo lifted. An individual country has an incentive to break an embargo since it can gain as long as all other countries stick to the embargo. A debtor country can also mitigate the consequences of an embargo by substitution. Therefore, the goods for which an embargo applies have to be adjusted on a regular basis.

Enforcing an embargo requires considerable determination. It must be monitored and adjusted continuously. Any slackening of efforts quickly leads to a deterioration of the embargo (Frey (1985)). The basic problems with an embargo are that where there is trade there is profit to be made and that it is very difficult to intervene in this process.

3.2.5 Costly sanctions

In summarising the analysis, the lenders' attitude can be characterised as follows: as long as the debtor country honours its obligations, nothing happens. If it does not, the lenders impose sanctions. The debtor country pays as long as the costs incurred by the sanctions are lower than the obligations. Bulow and Rogoff (1989a) show that this analysis is unsatisfactory if the sanctions also result in costs for the lenders. If this happens, it is not only necessary to resort to the possibility of imposing sanctions; lenders must also be willing to impose them.

Let us consider a debt contract with debt amount D and repayment obligation $S = (1 + r) D$. We assume that the lenders can seize assets worth Y. Obviously, the debtor country faces punishment costs $P = Y$. The debtor country now has two possibilities. It either pays S or it offers a new contract with repayment $0 \leq S' < S$. Since S' can be zero, default is already factored in. If the debtor country repays S, the contractual relationship ends. If the debtor country offers S' instead, and the lenders accept, the country pays S' and the contractual relationship ends. If instead the lenders reject the offer, they can impose sanctions. We assume that this leads to costs C for the lenders. On the one hand, C represents the costs of the renegotiation procedure, on the other hand it represents the possibly different valuation of the sanction. If the debtor country defaults and the lenders impose the sanction, the net gain for the lenders is $Y – C$. The debtor country, however, is left with nothing. If the debtor country offers $S' = Y – C$, the lenders are as well off and therefore agree. The country now is left with C. The debtor country therefore offers a renegotiated contract whenever $Y – C < S$. Anticipating this behaviour, the lenders are only willing to lend up to $D^* = (Y – C)/(1 + i) = (P – C)/(1 + i)$. The assumed strategic advantage of the debtor country affects it negatively ex ante since the lenders anticipate its strength. The lower the bargaining power of the debtor country, the weaker is the effect. In the extreme case of full bargaining power of the lenders, renegotiation has no influence on the initial contract. The possibility to renegotiate contracts strengthens the debtor country's position ex post and has negative consequences ex ante since the lenders protect themselves against the strength of the debtor.

As already mentioned, this result is driven by the sanctioning costs *C*. Note that these costs are pure dead weight losses. The bargaining procedure ensures that the sanctions do not take place, thereby leading to gain *C*. In fact, the parties bargain over how to split this gain. Assuming the information is symmetrical, this gain is always achieved (Coase Theorem). Since the bargaining solution is anticipated, it is implicitly incorporated in the original contract. Bargaining and sanctioning never take place. Bargaining power turns out to be a boomerang for the debtor country.

3.3 Reputation

Reputation as a disciplining mechanism constitutes a mixture of the carrot and stick approaches. Aerni and Egli (1999) analyse reputation as a basis for international lending. As in the standard reputation models (for an overview, see Fudenberg and Tirole (1991), Chapter 9), reputation effects are introduced by adding uncertainty. Aerni and Egli assume that some debtor countries pay their debt obligations in any case, whereas other countries weigh the pros and cons of contract fulfilment against repudiation. Trade restrictions, such as embargoes or the denying of trade credits, can serve as a threat to discipline the behaviour of the debtor. The assumption implies that for some countries trade is so important that they are vulnerable, and hence always willing to pay. Another possible explanation for the willingness to pay could be the different attitudes towards the future on the part of the government. Some regimes may be myopic and therefore maximise utility over short-term periods, whereas others may be more future-oriented, and are willing to bear costs today in order to profit tomorrow. While a debtor country knows whether or not it can successfully default on its debt, the creditor country is uncertain as to the type of debtor country it is dealing with. It only knows the strictly positive prior probability that the debtor will always pay. A so-called "bad" debtor country may have an incentive to build up a reputation of being a reliable debtor by mimicking the behaviour of a "good" country. Under some parameter constellations, reputation leads to contracts in a two-period game which would be irrational if only one period were considered.

The result also sheds light on the question of how and why international debt relationships are connected with default. In a reputational equilibrium, default has to be a possibility. If a bad debtor does not repay with a probability of less than one, there will be no lending. Default occurs as part of optimal play and is therefore simply a necessary by-product of international lending relationships. Whereas in the literature default occurs either due to unfavourable exogenous factors which the parties cannot write into a contract (see, for instance, Eaton et al. (1986) or Grossman and Van Huyck (1988)) or due to falsely high debt (Bulow and Rogoff (1989b), among others), in the model of Aerni and Egli default arises endogenously and is, as just mentioned, both necessary and unavoidable.

4. How global are global financial markets?

Sovereign countries can default on their debt. As the discussion so far has shown, the sovereignty of countries leads to a misallocation of capital, especially to countries which, based on their economic potential, should be debtors. For these countries, country risk is the major transaction cost. "Globalisation of financial markets" is based on the reduction of other transaction costs. For the countries for which country risk is the major cost, the reduction of other costs plays only a secondary role. Globalisation will stop at their borders. The analysis, however, also shows ways to integrate countries despite country risk. As we have seen, punishments are the driving force behind international lending. Industrial countries have access to international financial markets not only because most of them are small borrowers at best, but also because they are extremely vulnerable owing to their close trade relations. Integrating emerging market countries into world trade makes them vulnerable too, thereby enabling them to participate in international financial markets.

Bibliography

Aerni, Peter and Dominik Egli (1999): "Overcoming Time-Inconsistency in Sovereign Debt". Mimeo.

Allen, Franklin (1983): "Credit Rationing and Payment Incentives". *Review of Economic Studies*, 50, pp. 639-46.

Bulow, Jeremy and Kenneth Rogo (1989a): "A Constant Recontracting Model of Sovereign Debt". *Journal of Political Economy*, 97, pp. 155-78.

Bulow, Jeremy and Kenneth Rogo (1989b): "Sovereign Debt: Is to Forgive to Forget?". *American Economic Review*, 97, pp. 43-50.

Cole, Harold and William English (1991): "Expropriation and Direct Investment". *Journal of International Economics*, 30, pp. 201-27.

Eaton, Jonathan and Mark Gersovitz (1981): "Debt with Potential Repudiation: Theoretical and Empirical Analysis". *Review of Economic Studies*, 48, pp. 289-309.

Eaton, Jonathan, Mark Gerosvitz and Joseph Stiglitz (1986): "The Pure Theory of Country Risk". *European Economic Review*, 30, pp. 481-513.

Fudenberg, Drew and Jean Tirole (1991): *Game theory*. MIT Press, Cambridge, Mass. and London.

Frey, Bruno (1985): Internationale Politische Oekonomie, München.

Grossman, Herschel I and John B Van Huyck (1988): "Sovereign Debt as a Contingent Claim: Excusable Default, Repudiation, and Reputation". *American Economic Review*, 78(5), pp. 1088-97.

Kletzer, Kenneth (1984): "Asymmetries of Information and LDC Borrowing with Sovereign Risk". *Economic Journal*, 94, pp. 287-307.

Niehans, Jürg (1986): "Internationale Kredite mit undurchsetzbaren Forderungen". *Schriftenreihe des Vereins für Socialpolitik*, 155, pp. 151-79, Berlin.

Asian crisis post-mortem: where did the money go and did the United States benefit?

Eric van Wincoop and Kei-Mu Yi[1]

1. Introduction

The recent currency crises in Asia have raised important questions about the sensitivity of industrialized economies to financial crises in faraway emerging markets. In late 1997 and 1998, Indonesia, Korea, Malaysia, the Philippines and Thailand (Asia-5) experienced net capital outflows of about $80 billion, plunging them from "growth miracle" status into the worst recession they had seen in decades. GDP growth rates for 1998 in Korea and Malaysia were –5.8% and –7.5%, respectively, and in Indonesia and Thailand the GDP declines exceeded 10%. In the United States, however, 1998 turned out to be a strong year, with GDP growth coming in at +4.1%.

Is there a connection between the crisis in Asia and the strong US growth performance? Sequential correlation, of course, does not imply causation. The US economy could have been robust for many reasons, including the "new" productivity revolution and the reductions in the federal funds rate in late 1998. In addition, most economists thought the downturn in Asia would exert a *negative* effect on the US economy. Recessions in the crisis countries, in conjunction with sharply depreciated currencies, would reduce their demand for imports from the United States. Moreover, the currency depreciations would lead to an export surge to the United States. Hence, through this international trade channel, US net exports were predicted to contribute more negatively to growth than had been expected prior to the crisis. Indeed, the US trade deficit did increase, contributing –1.1% to US GDP growth in 1998. However, the increase in the deficit was more than offset by continued strong increases in employment and production, in conjunction with continued robust spending on consumer goods and on producers' durable equipment. Quarter by quarter, US GDP growth in 1998 consistently exceeded projections.

In our view, these (apparently) surprising outcomes reflect the fact that the original way of thinking about the crisis was flawed. First, the depreciation of the Asian currencies against the dollar and the recessions in the Asian crisis countries were endogenous responses to a large and sharp reallocation of capital out of the Asian crisis region. From the point of view of the United States, this reallocation of capital is the appropriate starting point – not the depreciations and recessions – when thinking about the implications of the crisis for the US economy.[2] Second, the original way of thinking focused only on demand-side channels, ignoring the supply side.

While the reallocation of capital towards the United States generated the above-mentioned negative trade effects on US GDP, the capital inflows also generated a positive effect on US GDP by financing an increase in US spending, both directly and indirectly by generating a drop in interest rates. The capital inflows also led to an appreciating dollar, which made imported inputs cheaper. These cheaper inputs generated a positive effect on GDP similar to the effect of a positive productivity shock. For these two reasons then, rather than viewing the strong US growth performance in 1998 as having

[1] The views expressed in the paper are those of the authors and are not necessarily reflective of views at the Federal Reserve Bank of New York or the Federal Reserve System. We thank Barbara Berman, Chris Gorband and Russ Scholl of the Bureau of Economic Analysis, and Dan Kinney, Sydney Ludvigson, Therese Melfo, Don Morgan, Dick Peach, Monica Posen, Charles Steindel and participants at two Research Department brown bags for very helpful comments. Scott Nicholson and Stefan Papaioannou provided outstanding research assistance.

[2] One can of course go a step further and say that the analysis should start with the factors that led to the capital outflow from Asia in the first place. But from the point of view of the US economy, the exact cause of the reallocation of capital is not critical.

occurred despite the Asian crisis, we view the strong performance as having occurred because of the Asian crisis.

As the crisis proceeded, and US growth remained strong, a new story along the lines sketched above, with capital inflows into the United States as the centerpiece, became increasingly popular. Yet surprisingly, there is very little documentation of this story. This paper aims to at least partially fill that gap. Specifically, we first attempt to document the trail of capital out of Asia and into the United States. We then analyze and quantify the implications for short-run US GDP growth of the (direct and indirect) reallocation of capital from Asia to the United States.

It is not difficult to document the "beginning" and the "end" of the money trail insofar as it involves the Asian countries and the United States. Capital outflows from the Asia-5 from the start of the crisis (1997Q2) to the end of 1998 amounted to about \$80 billion. The United States ran a current account deficit in 1998 of \$221 billion, an increase of \$77 billion over the 1997 current account deficit. The increased deficit was obviously financed by increased capital inflows.

It is more difficult, however, to document the precise trail of money from these Asian countries to the United States. Using Bank for International Settlements (BIS) data, and data drawn from the US Treasury Department's Treasury International Capital (TIC) system, we are able to follow the trail to a certain extent. We find that banking flows were the major source of the outflows, and that these outflows were dispersed all over the world, including Japan, Europe, the United States and offshore banking centers. The majority of the flows went to the offshore centers. Our findings also suggest that most of the offshore centers funneled their money to European banks. From there the trail runs cold, but we do conclude that banks clearly played an important role at the beginning of the reallocation process, and the money clearly came to the United States in a roundabout fashion.

It is difficult to ascertain exactly in what form (banking, portfolio or direct investment) and from exactly what countries the Asian crisis money entered the United States. We assume that the initial "rounds" of bilateral international money flows – the flows from the Asian crisis countries to the rest of the world and from the offshore centers to the rest of the world – arise directly from the Asian crisis, but this assumption clearly becomes more untenable as the money trail gets longer. In addition, the net errors and omissions component of the US balance of payments is typically large and, more importantly, it tends to spike during crises. At times, the change in errors and omissions is often large enough to cancel out even the largest changes in reported capital flows.

In analyzing the impact of the crisis on short-run US GDP growth, we consider three channels. The first is the trade channel, which has a negative impact on growth. The second is a domestic demand channel. The capital inflows finance an increase in domestic demand. The third is a supply channel. The appreciation of the dollar against the Asian currencies leads to a decrease in prices of imported inputs. We illustrate these effects in the context of a simple model of goods market and balance of payments equilibrium. We then provide evidence consistent with each of these channels and quantify their impact on US GDP growth. We find that the net effect of the Asian crisis on US growth was small but positive, +0.2 percentage points, confirming the newer wisdom.

The remainder of the paper is organized as follows. Section 2 documents the trail of money out of the Asian crisis countries. Section 3 examines the inflow of capital to the United States. Section 4 analyzes and quantifies the impact of the crisis on US growth. Section 5 concludes.

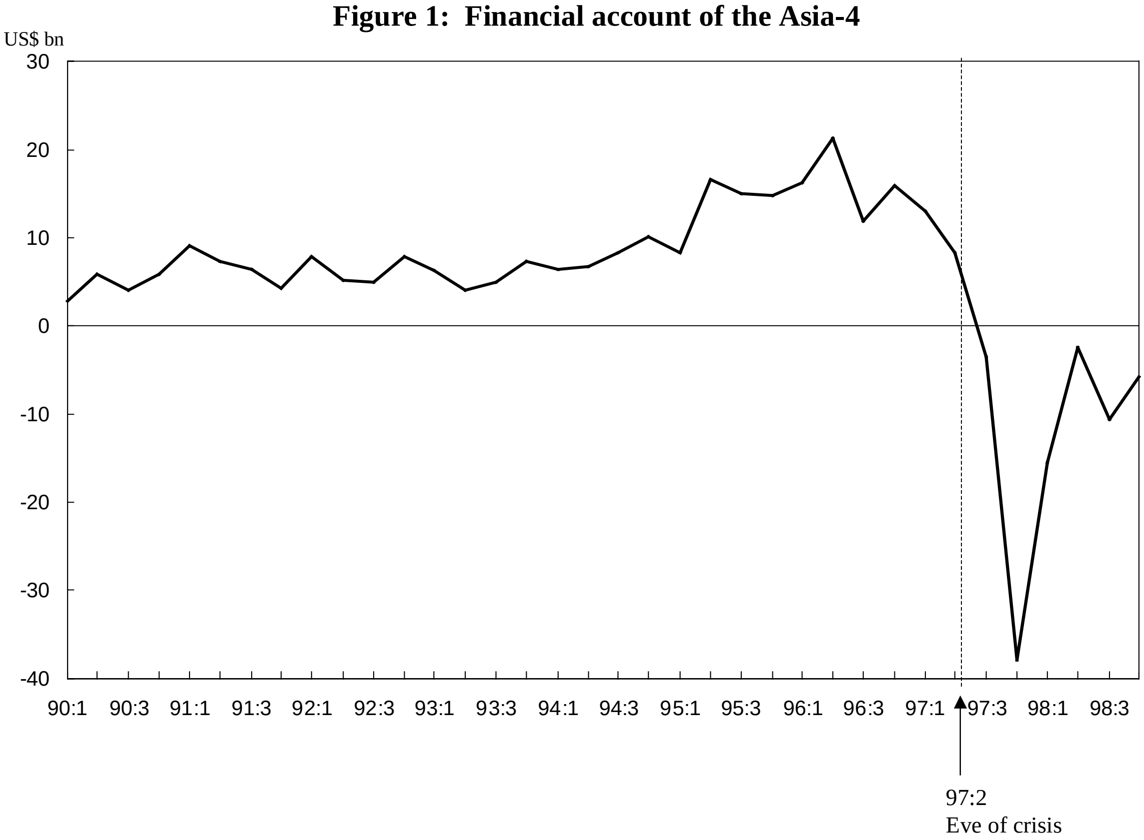
2. Outflow of capital from Asian crisis countries

Figure 1 illustrates the sharp and sudden net capital outflow from the "Asian-4" crisis countries, which are Indonesia, Korea, the Philippines and Thailand.[3] The Asia-4 countries experienced positive net

[3] Although Malaysia is often included as one of the crisis countries, we do not include it in the figures because of incomplete data, particularly the breakdown of the financial account into portfolio investment, foreign direct investment

capital inflows throughout the 1990s. Then in 1997Q3, a sharp outflow began. In the six quarters from 1997Q3 to 1998Q4, these countries experienced a net outflow of $77.9 billion. By contrast, in the six quarters prior to the crisis, they experienced a cumulated net inflow of $86.8 billion. Even today, these countries continue to experience net capital outflows.

Figure 1: Financial account of the Asia-4



If the financial account (we will use the terms "financial account" and "capital account" interchangeably) is broken down into portfolio flows, foreign direct investment (FDI) flows and "other" flows, Figure 2 shows that the bulk of the outflows since the onset of the crisis consisted of other flows.[4] Indeed, other flows account for more than 100% of total net outflows, with a cumulative outflow of $84.9 billion from 1997Q3 to 1998Q4. During this period, $46.2 billion, equivalent to 59.3% of total outflows, were bank flows, that is, flows involving Asia-4 banks. Most of the remaining other flows appear to involve non-bank financial institutions.

Figure 3 suggests that the counterparties to the flows involving Asia-4 banks were almost surely BIS reporting banks, which include banks from most of the OECD countries as well as several offshore centers in the Caribbean, Hong Kong and elsewhere.[5] The figure shows exchange rate adjusted net lending flows from the BIS reporting banks to the Asia-4. Both the increase in net lending in the years preceding the crisis and the sharp reduction in net lending by these banks after 1997Q2 closely mirrors

---

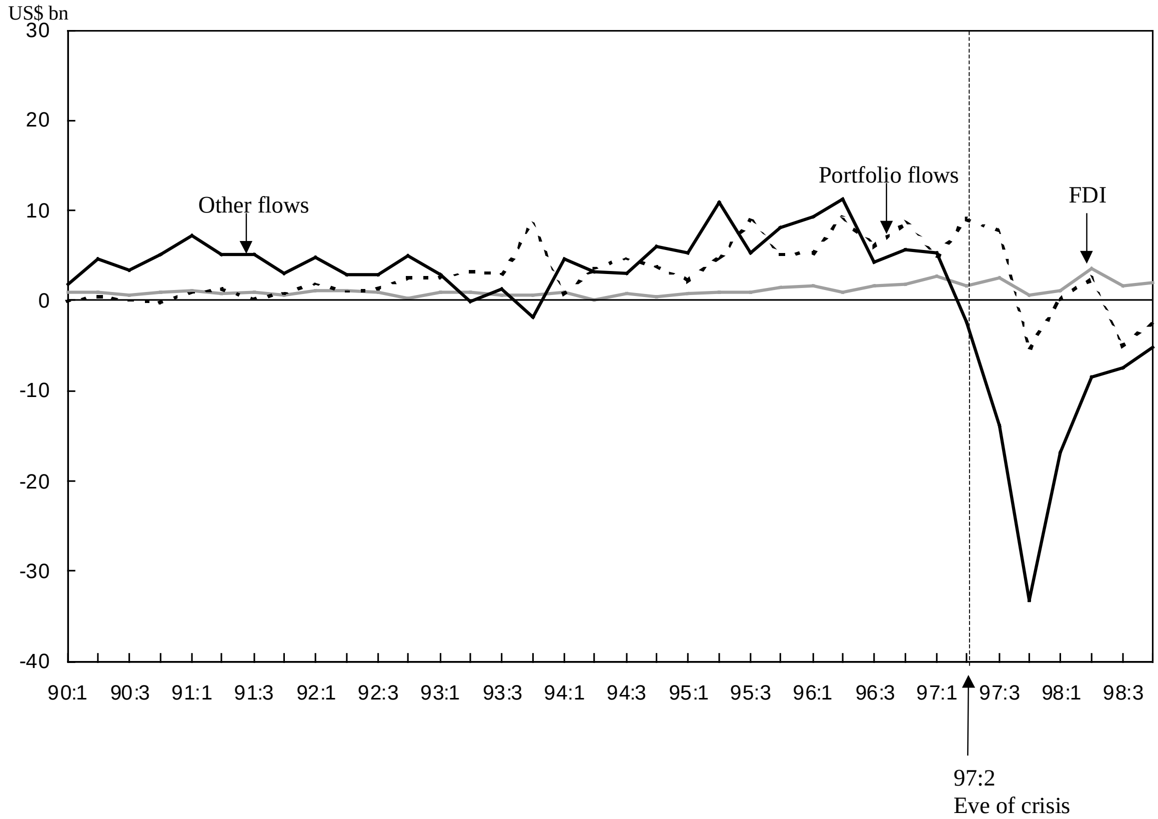
and other investment. We do include Malaysia in a broader set of eight Asian countries when we consider the effect of the crisis on US growth in Section 4.

4 Direct investment refers to international flows of "equity capital, reinvested earnings, and other capital associated with various inter-company transactions between affiliated enterprises" (IMF (1999)). It generally refers to both greenfield investment and mergers and acquisitions. Portfolio investment refers to international flows of debt and equity (except equity counted as direct investment) securities of any maturity. Other investment primarily involves financial transactions with non-residents by banks and non-bank intermediaries.

5 The offshore centers include the Bahamas, Bahrain, the Cayman Islands, Hong Kong, the Netherlands Antilles and Singapore.

the overall capital inflows and outflows from the Asia-4 depicted in Figures 1 and 2.[6] The cumulative net lending flows from 1997Q3 to 1998Q4 equal a net outflow of $105.3 billion. This is equivalent to about one third of the total stock of claims against these countries in 1997Q2! Figures 2 and 3 taken together suggest that most of the capital outflows involved banks on both sides – Asia-4 banks on the one hand and BIS reporting country banks on the other.

Figure 2: Breakdown of the financial account of the Asia-4



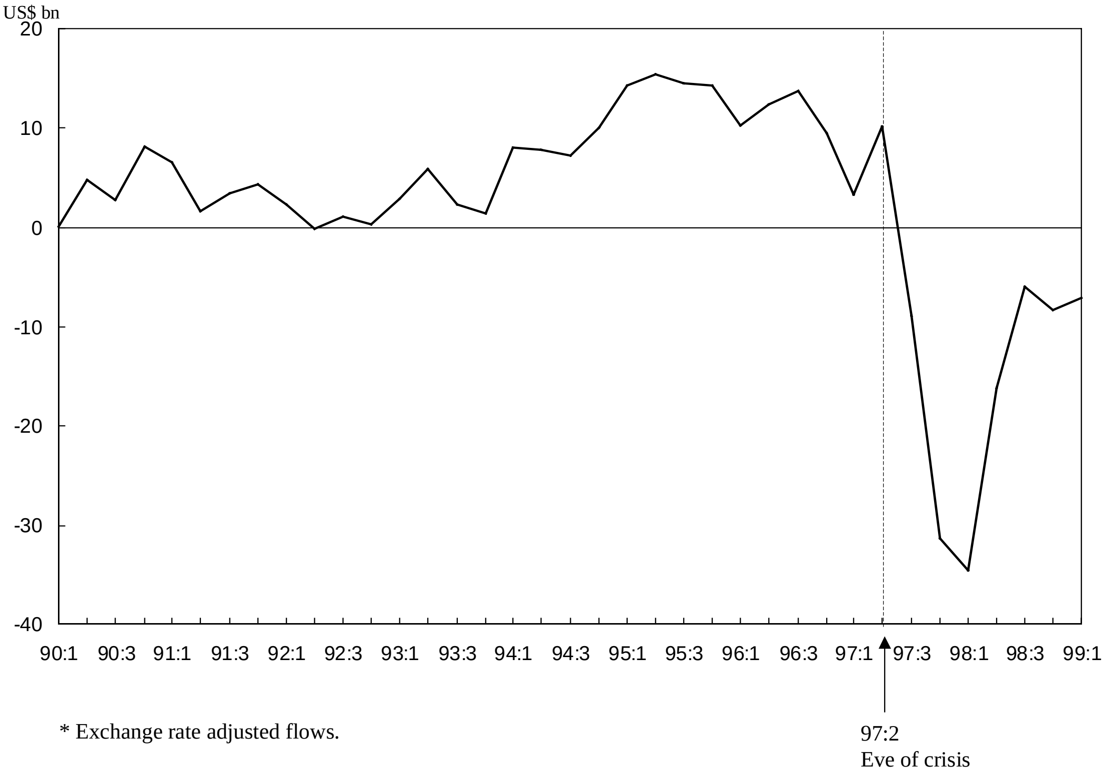
Which countries were the largest sources of the reduction in net bank lending to the Asia-4? There are two ways to address this question. One way views countries as geographical locations. The other way views countries as representing nationalities. For example, a Swiss bank subsidiary operating in the United States would count as a US bank based on geography, and as a Swiss bank based on nationality. The two ways complement each other because the geographic approach is consistent with balance of payments data on capital flows, while the nationality approach helps control for the fact that many cross-border banking flows involve borrowing and lending by banks with their subsidiaries in other countries. This is especially true for banks that have branches or subsidiaries in offshore centers.

We begin with the geographical approach. Figure 4 reports net bank lending flows to the Asia-4 by geographical location of BIS reporting bank. It focuses on four regions: Japan, Europe-7, the United States and its International Banking Facilities (IBFs), and offshore centers. Europe-7 comprises France, Germany, Italy, the United Kingdom, Switzerland, the Netherlands and Spain. While banks in all four regions reduced their net lending to the Asia-4, the reductions in Japan, Europe-7 and the United States were typically of the order of several billion dollars per quarter. The figure shows clearly that the majority of the outflows from the Asia-4 were accounted for by the offshore centers, with $54.3 billion out of the total net outflow of $105.3 billion.

---

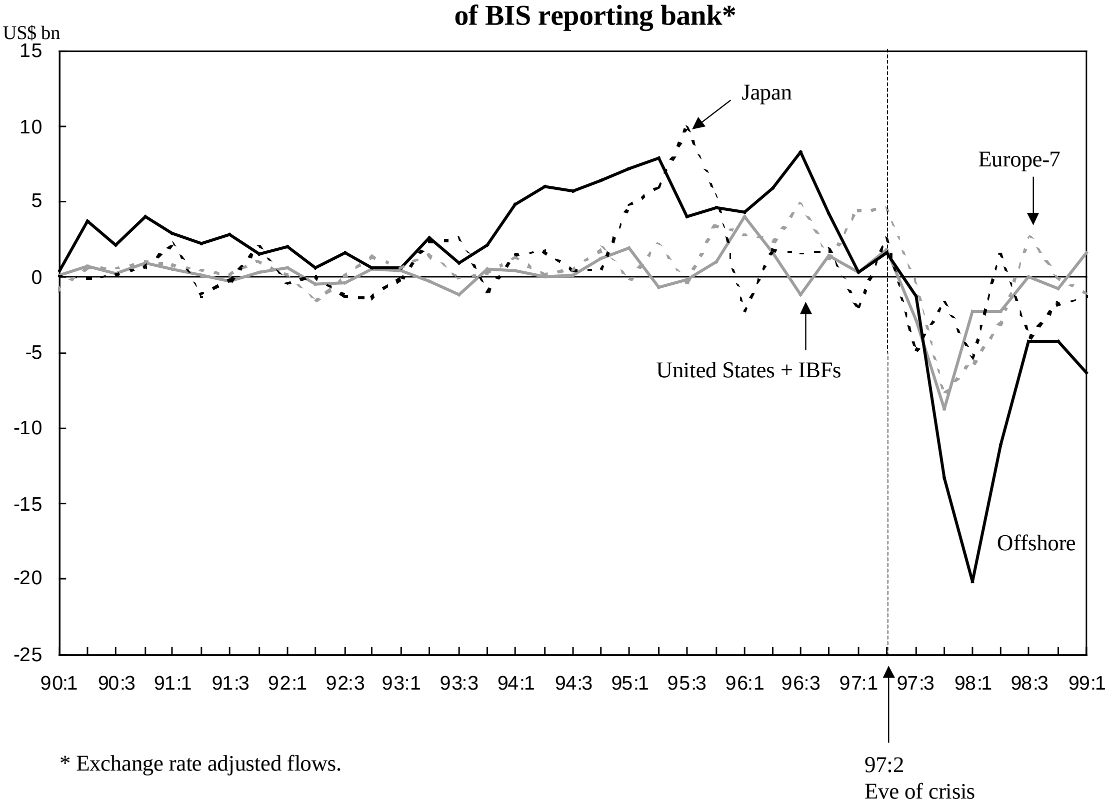
6 The only difference of note is that in 1998Q1 the extent of the capital outflow from the Asia-4 was lower than in the previous quarter, while the reduction in net lending by BIS reporting banks was slightly larger.

Figure 3: BIS reporting banks' net lending to the Asia-4*



* Exchange rate adjusted flows.

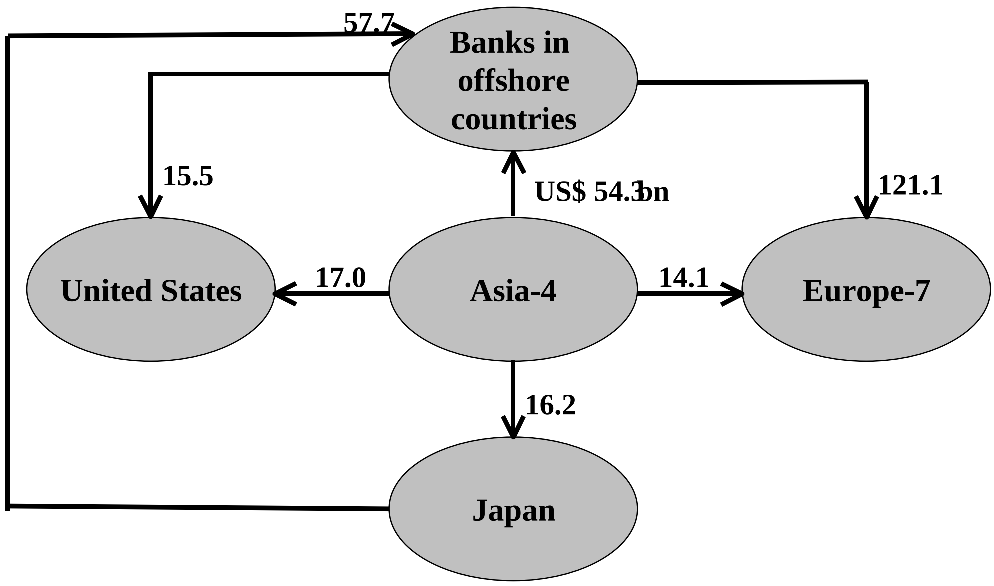
Figure 4: Net bank lending to the Asia-4 by geographic location of BIS reporting bank*



* Exchange rate adjusted flows.

Because the economies of the offshore centers are relatively small, we presume that most of their inflows must generate corresponding outflows. To a large extent, one can therefore view these centers as "pass-through stations".[7] Figure 5 illustrates this in the form of a flow diagram. The figure reports net cumulative bank lending of BIS reporting countries over the 1997Q3-1998Q4 period. Banks in offshore centers received $112.0 billion in net inflows from the Asia-4 and Japan between June 1997 and December 1998. Most of this money went to banks in the Europe-7, which experienced a $121.1 billion net inflow from the offshore centers.

Figure 5: Flow diagram of net lending of BIS reporting banks: June 1997 to December 1998



Notes: The flows out of Asia-4 correspond to an increase in net liabilities vis-à-vis Asia-4 of the BIS reporting banks in the offshore countries, the United States, Europe-7 and Japan. The flows of the offshore countries vis-à-vis the United States, Europe-7 and Japan correspond to net lending by banks in the offshore countries to both banks and non-banks in the United States, Europe-7 and Japan.

What is also striking from Figure 5 is the minimal amount of banking inflows to the US originating directly from the Asia-4 or mediated through the offshore centers. The money associated with the Asia-4 capital outflow could of course have reached the US banks via more indirect channels, such as through Europe, or even from Japan by way of the offshore centers and Europe. Once the flows become so indirect, however, it becomes difficult to trace the original source of the money. This is already apparent in Figure 5. More money entered the offshore centers from Japan than from the Asia-4. Therefore, we cannot conclude that the money exiting the offshore centers is directly connected to the Asia-4 outflows. This exiting offshore money could also be the result of net capital outflows from Japan connected to its own economic downturn.

The top row of Table 1 shows that of the $105.3 billion reduction in lending, $98.5 billion represented declines in claims on the Asia-4. Hence, we find that most of the adjustment is on the claims side. We also find that, even though a not insignificant fraction of the BIS bank loans were denominated in domestic currencies, the exchange rate adjusted flows are almost identical to the change in the stock of

---

7 In other words, we assume that these countries typically have small current accounts and small net changes in central bank reserves. This is a reasonable assumption for all of the offshore centers except Hong Kong and Singapore. Total net cumulative external lending of the offshore centers was $29 billion during this period. However, this is a relatively small fraction of the gross flows in and out of these centers. By contrast, during the crisis, the Asian crisis-country gross flows were similar in magnitude to the net flows.

claims less liabilities. This is shown in the second row of Table 1. The reduction in stocks was $106.3 billion and the reduction in claims was $99.4 billion. These two findings are useful, because they allow comparisons to be made between the geography-based data and the nationality-based data. The nationality-based data are only available for claims (not liabilities) and are only available for stocks of claims (rather than exchange rate adjusted flows).

Table 1

Change in assets and liabilities of BIS reporting banks vis-à-vis the Asia-4
(June 1997 to December 1998; in billions of US dollars)

		Assets	Liabilities	Net claims
		Geographical breakdown		
Cumulative exchange rate adjusted flows		**–98.5**	**6.8**	**–105.3**
Change in stocks:	All BIS countries	**–99.4**	**6.9**	**–106.3**
	Offshore countries	–51.3	2.8	–54.1
	United States	–14.9	2.1	–17.1
	Europe–7	–11.4	2.6	–14.0
	Japan	–18.4	–0.8	–17.6
		Nationality breakdown		
Change in stocks	All nationalities	**–79.7**	-	-
	United States	–7.6	-	-
	Europe-6	–11.2	-	-
	Japan	–28.6	-	-
	Other nationalities	–32.3	-	-

Notes: The geographical breakdown refers to all banks located in BIS reporting countries. The nationality breakdown refers to all banks located in non-offshore BIS reporting countries, plus the foreign affiliates of these banks if they have the nationality of one of the non-offshore BIS reporting countries. This means that banks in offshore countries with nationalities other than those of the non-offshore BIS countries are not included in the nationality breakdown, even though they are included in the geographical breakdown. This accounts for the small discrepancy between the totals based on the geographical and nationality breakdowns. The nationality data are only available for claims. Europe-7 comprises the United Kingdom, Germany, France, Italy, the Netherlands, Spain and Switzerland. Europe-6 excludes Switzerland. Banks of Swiss nationality in Switzerland are included in the total for the nationality breakdown, but are not included in the European nationality subcategory.

The bottom panel of Table 1 provides a summary of bank lending to the Asia-4 by nationality. Time series of both the geographical and nationality data are shown in Figure 6 as well. Of the $79.7 billion reduction in assets that can be assigned to nationalities, only $47.6 billion involves the United States, the Europe-6 (Europe-7 less Switzerland) and Japan. This is surprising. The remaining $32.3 billion is accounted for by banks of other nationalities operating in the BIS countries, which would include Thai and Korean banks operating in the United States, for example. A detailed breakdown of this remainder is unavailable. Note that the outflows based on the nationality data are $19.7 billion less than the outflows based on the geographical breakdown. The reason is that banks operating in the offshore centers are not included in the nationality breakdown if their nationality is not that of one of the non-offshore BIS reporting countries. For example, banks of Hong Kong nationality operating in Hong Kong are not included in the nationality breakdown, while they are included in the geographical breakdown. The same is true for a Saudi Arabian bank operating in Hong Kong. In summary, less than half of the total banking outflow from the Asia-4 is accounted for by US, Japanese or Europe-6-owned banks. Only $7.6 billion is associated with banks of US nationality.

We note parenthetically that the Asia-4 current account was initially buffered from the large capital outflows by IMF credit and a rundown of reserves. This is illustrated in Figure 7. It is worthwhile recalling that from a balance of payments perspective, a rundown of central bank foreign exchange reserves is a net official capital inflow, which accounts for about half of the rise in reserves. The other half is associated with the increase in IMF credit. Figure 7 shows that the full current account adjustment did not take place until the first quarter of 1998.

Figure 6: Source of BIS reporting bank claims on the Asia-4

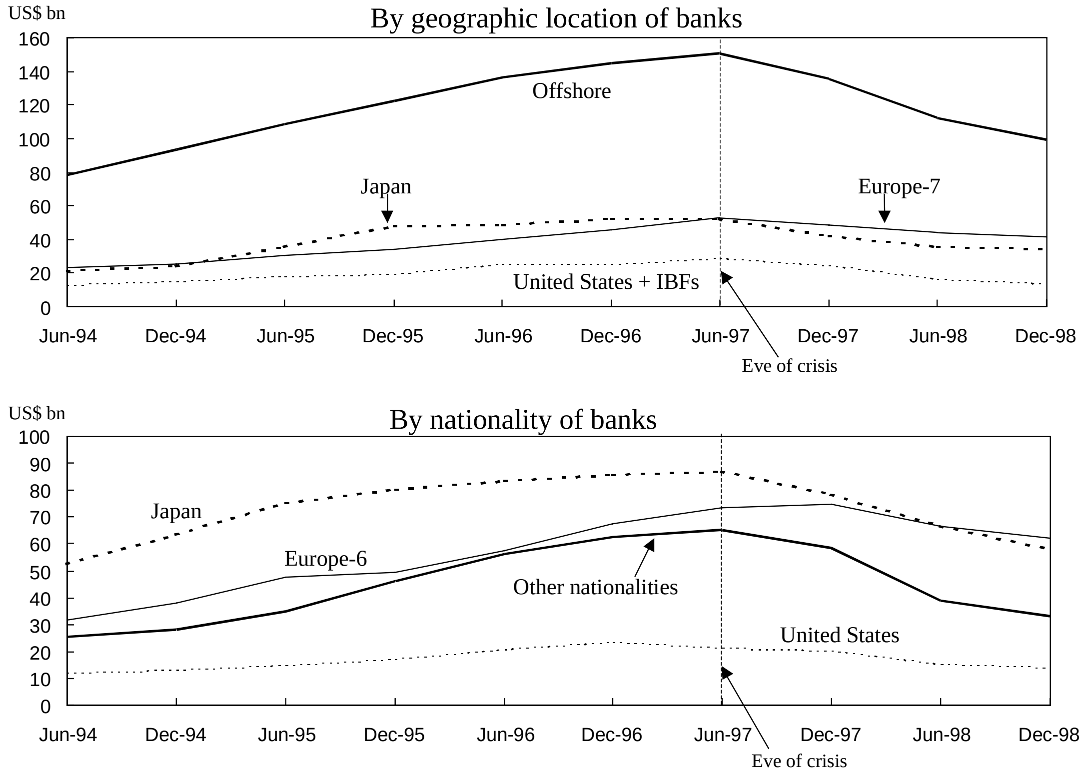
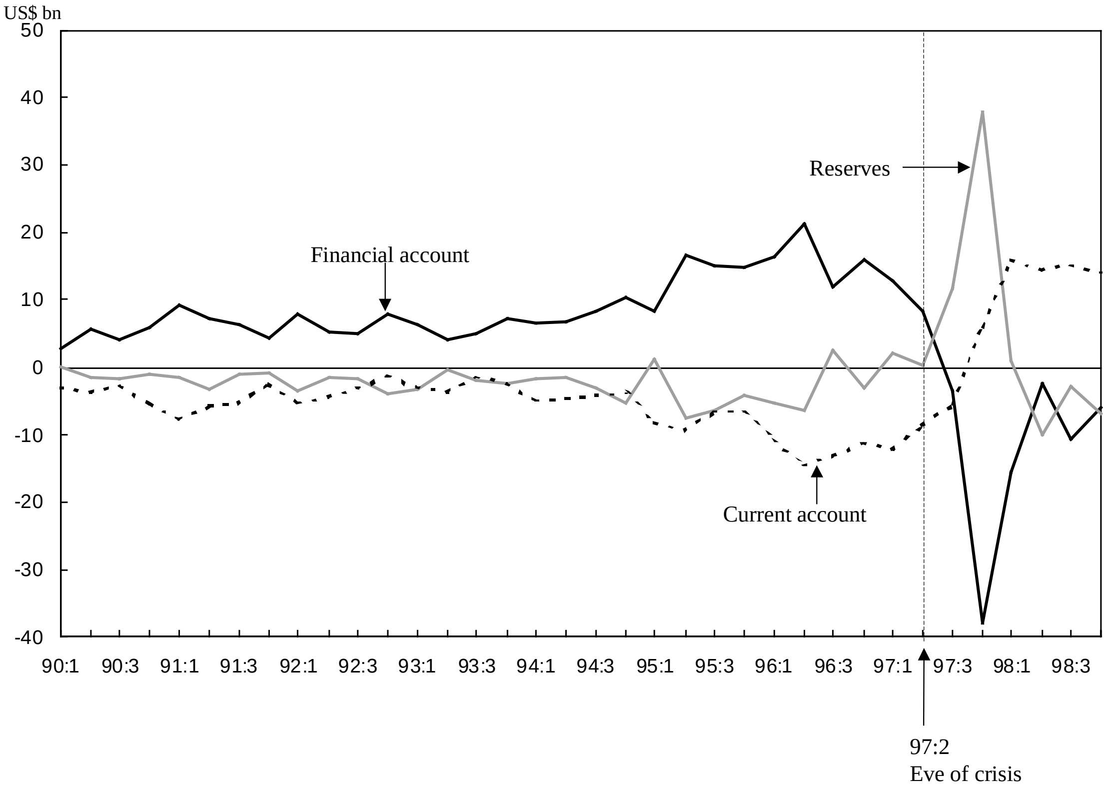


Figure 7: The Asia-4 current account versus the financial account



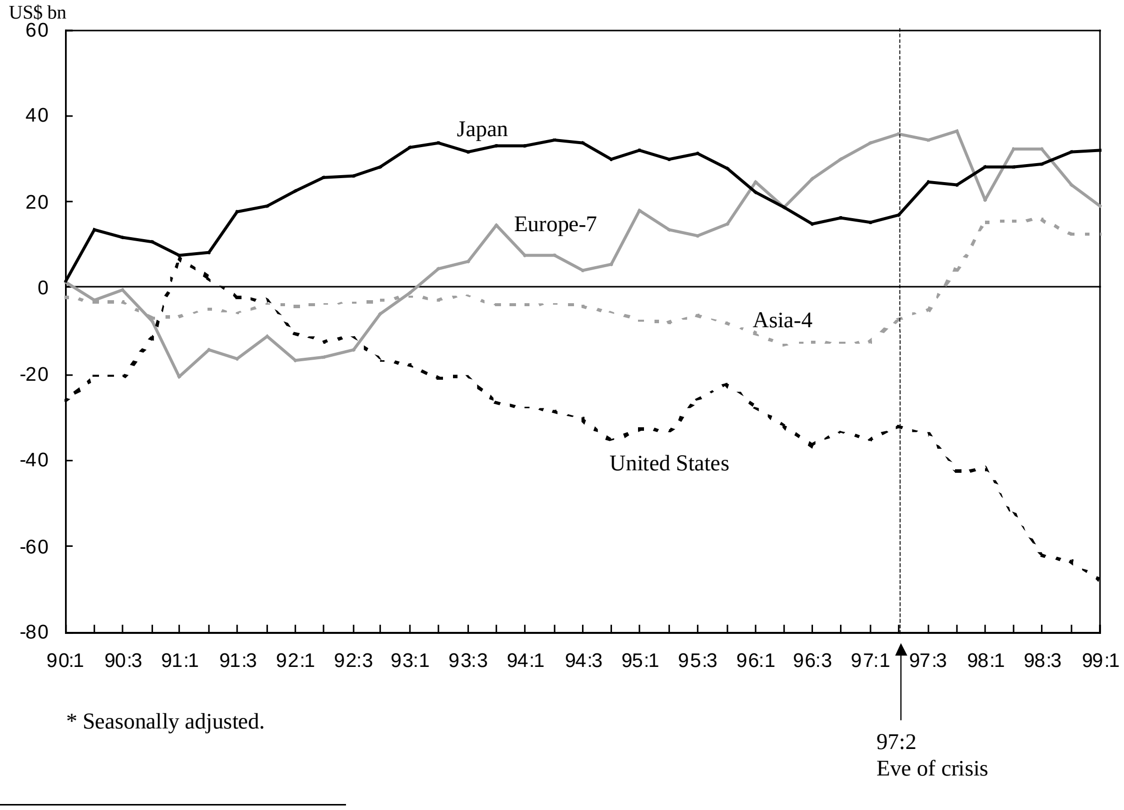
To summarize, banks played a large role in the immediate outflows from Asia. Most of the immediate outflows went to offshore center banks. The offshore center banks, in turn, played a large role in funneling these outflows to banks in Europe. Once the money reached Europe it became part of a vast pool of capital. We would expect that it is difficult to follow from there. Consequently, in the next section we focus on how the capital flows entered the United States.

3. Capital flows to the United States in the wake of the crisis

Turning our attention from the Asia-4 outflows to the US inflows, Figure 8 illustrates the seasonally adjusted quarterly current account balances of Japan, the Europe-7, the Asia-4 and the United States. The figure shows that the United States experienced a large deterioration of its current account. From 1997Q2 to 1999Q1, the quarterly US current account deteriorated by $35.1 billion. The Asia-4 current account improved by $19.7 billion during this period. Including Malaysia, the improvement was $26 billion.[8] Japan also experienced an improvement in its current account.

The figure gives the strong impression that most, if not all, of the capital outflows from Asia went to the United States. This impression is not completely warranted. Since 1991, the US current account has been trending downwards and the Europe-7 current account has been trending upwards. Because US GDP growth rates throughout this period have been higher than European growth rates, it is entirely possible that these trends would have continued in the absence of the crisis. We fit a simple linear time trend to the two current accounts using the data from 1990Q1 to 1997Q2. Extrapolating forward to 1999Q1, we find that the actual Europe-7 current account was about $20 billion below trend and the actual US current account was about $25 billion below trend. Hence, relative to trend, both regions' current accounts deteriorated by similar magnitudes. This evidence, coupled with the evidence of the previous section, suggests that both the United States and Europe experienced substantial capital inflows connected to the Asian crisis.

Figure 8: Current account balance*



* Seasonally adjusted.

8 The Malaysia figure is for 1998Q4.

From the previous section, we also know that very little of the Asian crisis-related capital flows to the United States took the form of direct flows from the Asia-4 to the United States. This is further illustrated in Figure 9. US banks' net lending to the Asia-4 fell by about $10 billion from 1997Q2 to 1997Q4, but the reduction in net lending was relatively short-lived as negative net lending was less than $2 billion from 1998Q1 onwards. By contrast, total net US capital inflows averaged $68 billion quarterly between 1997Q3 and 1998Q4. Figure 9 also illustrates net portfolio flows during this period. The portfolio flows include both long-term portfolio flows and changes in the holdings of US Treasury bills by the Asian countries. Interestingly, the portfolio flows move in the opposite direction to the bank flows. The net portfolio outflow from the United States to the Asia-4 in the midst of the crisis (at the end of 1997) is probably the result of the sale of treasury securities by central banks in the Asian countries.

Our evidence, then, indicates that there were large capital flows to the United States (and Europe) as a result of the Asian crisis, but that they reached the United States in a roundabout fashion, going through several countries before eventually ending up in the United States. To the extent that these flows were intermediated through banks, we would expect to see a surge in net flows to US banks (or equivalently, a decrease in net external lending by the US banks). The top panel of Figure 10 shows that this was not the case. While inflows to the United States increased by about $40 billion in 1997Q4, there was an equally large outflow in 1998Q1. The cumulative net inflow over the entire period between 1997Q3 and 1998Q4 was only $8.4 billion. The bottom panel of the figure breaks down the net lending by region (Europe-7, offshore and Japan). Although there was an increase in net flows from Japan to US banks from the beginning of the crisis, there was also a similarly large increase in net flows from US banks to Europe.

Hence, while BIS banks accounted for virtually all of the net outflows from Asia, we also know that the net capital flows into the United States were not intermediated through US banks. Other intermediation channels exist. European banks, for example, could have shifted lending from Asia to local institutions, which could then have used the money for foreign direct investment or portfolio investment in the United States. Indeed, cumulative net inflows to the United States from 1997Q3 to 1998Q4 associated with foreign direct investment and portfolio investment were $326.9 billion. Of course, given the large US current account deficits, a substantial portion of these flows would have occurred anyway.

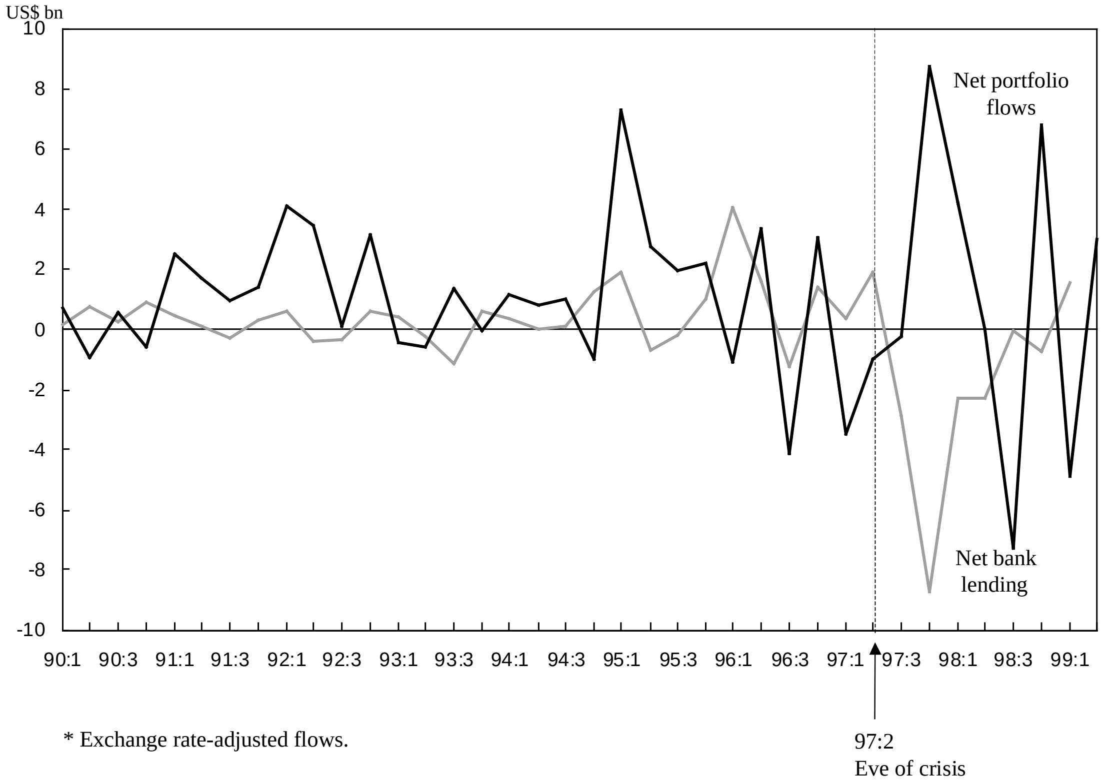
A key difficulty with using the US balance of payments data is that errors and omissions (the statistical discrepancy) were very large and volatile subsequent to the crisis. Between 1997Q2 and 1998Q4, cumulative errors and omissions were –$92.6 billion, implying that net capital inflows were $92.6 billion less than actually reported during this period.[9] Also, from 1997 to 1998, net errors and omissions rose by $152.7 billion, suggesting that actual capital inflows increased by $152.7 billion more than reported. Because the current account deficit increased by $76.7 billion from 1997 to 1998, capital inflows should have shown a similar increase. Instead, reported capital inflows showed a decrease of $70.8 billion.

Figure 11 shows that changes in net errors and omissions were also very important in many of the key quarters. For example, in 1997Q4 the United States experienced a net capital inflow of $114 billion dollars, an increase of about $40 billion from the previous quarter. The current account deficit was $41 billion, a $4 billion decrease over the 1997Q3 deficit. The errors and omissions of –$73 billion thus represented a change of –$44 billion relative to the previous quarter. This suggests that the increase in US capital inflows in 1997Q4 might not have happened. Similarly, the data show a sharp drop in capital inflows in 1998Q1, but this drop is again offset by a movement in errors and omissions in the opposite direction. There are several other episodes, such as during the Mexican crisis in 1994 and 1995, where changes in errors and omissions are of the opposing sign to changes in the financial account. It is difficult to infer much from the US capital flows data.

---

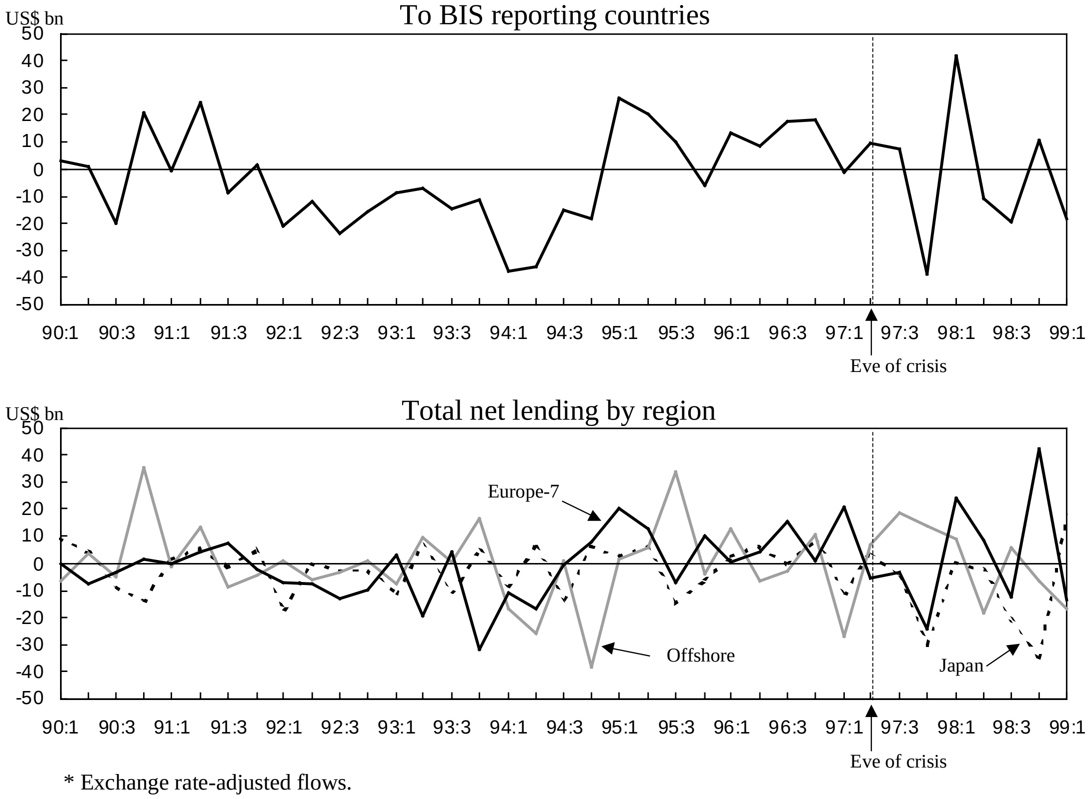
[9] This assumes that all the errors occur because of misreporting of the capital account data. In other words, we assume that the current account data are accurately represented.

Figure 9: Net lending of the United States to the Asia-4*



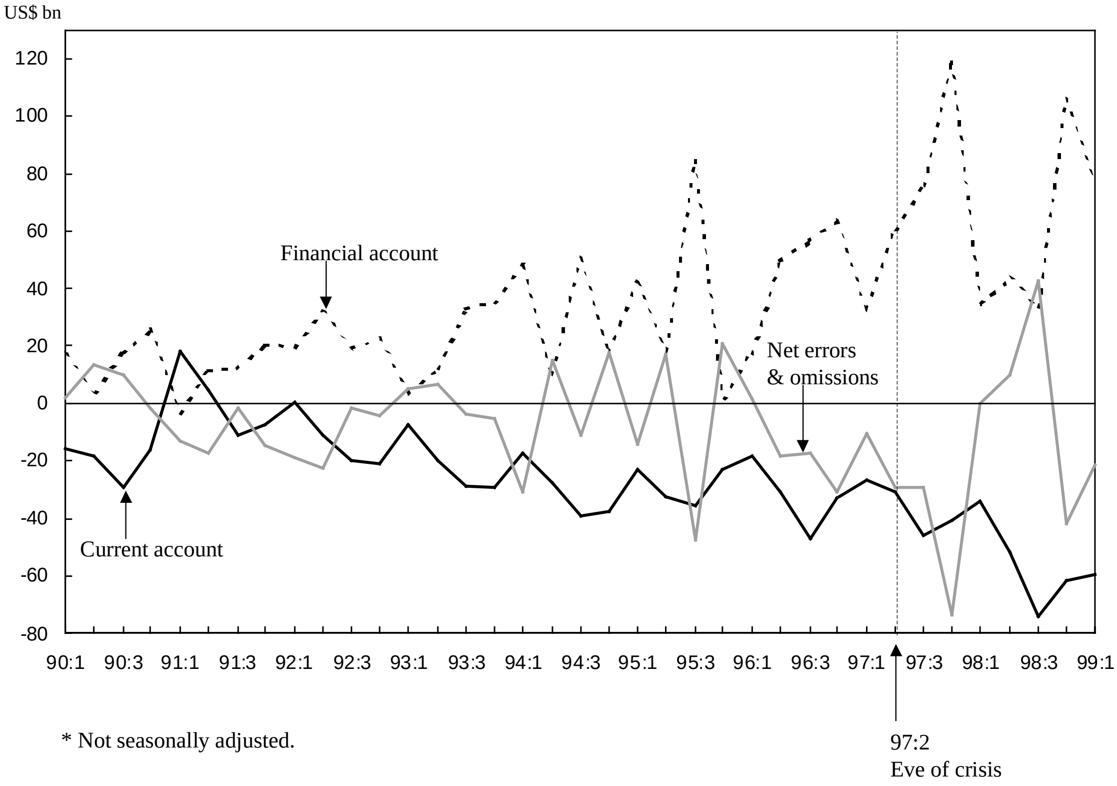
* Exchange rate-adjusted flows.

Figure 10: Net lending by US banks*



* Exchange rate-adjusted flows.

Figure 11: US balance of payments*



* Not seasonally adjusted.

Figure 12: Euro/$ and Yen/$

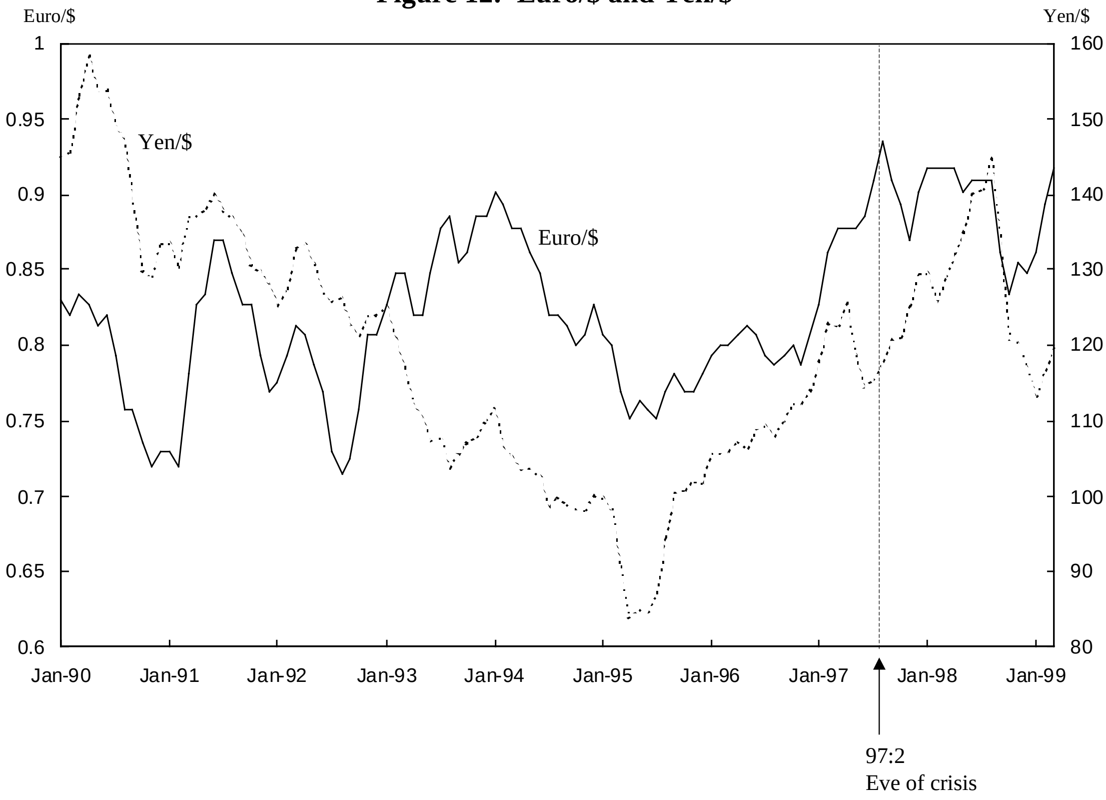
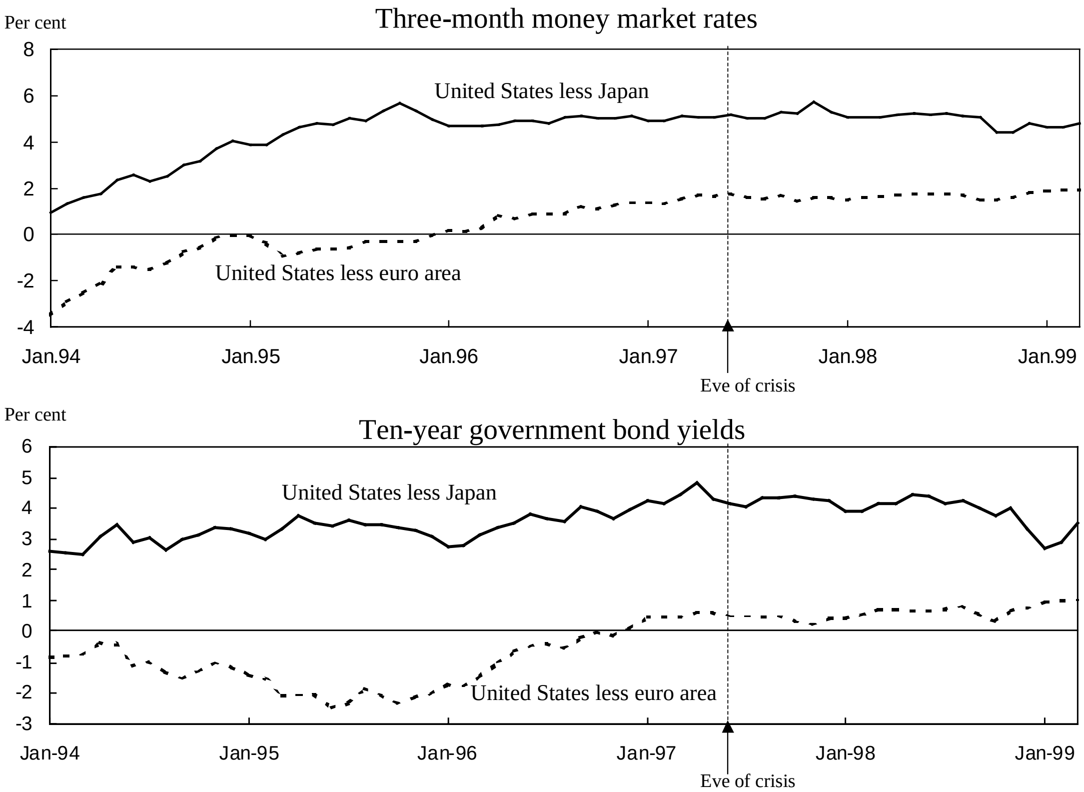


Figure 13: Interest rate differentials



Finally, we consider the possibility that the United States functioned as a "safe haven" during this period. In this scenario, foreign investors shifted their capital – including capital from other industrialized countries – en masse to the United States during the time of crisis. Two simple implications arise from the safe haven scenario. First, we would have expected the dollar to have significantly appreciated against other industrialized country currencies and, second, we would have expected the US interest rate to have dropped relative to those in other industrialized countries. Figures 12 and 13 show that neither implication is the case. The dollar did appreciate against the yen, but the appreciation was short-lived and by the end of 1998 the dollar's yen value had fallen to pre-Asian crisis levels. The euro/dollar rate was fairly stable in the first five quarters after the crisis. Both short-term and long-term interest rate differentials showed no sign of change either. This evidence suggests that there was not a significant safe haven effect in response to the Asian crisis. This evidence is also consistent with our earlier evidence that both the United States and Europe experienced large capital inflows connected to the Asian crisis.

4. Did the United States GDP increase?

As discussed in the introduction, there are at least three important channels through which the crisis in the Asian emerging markets could have affected the US economy:

1. Net export demand channel (negative)

2. Domestic demand channel (positive)

3. Supply channel (positive)

The outflow of capital from the Asian emerging markets leads to an appreciation of the dollar and a recession in the affected countries. Both forces lead to a reduction in US net exports (channel 1). Second, to the extent that the capital that is pulled out is reinvested in the United States, it can be used to finance an increase in US consumption and investment (channel 2). In the process, US interest rates are likely to fall. Finally, the dollar appreciation and the emerging markets' recessions lead to lower US import prices for intermediate and capital goods, which exerts a positive supply effect (channel 3).

These three effects are obviously interrelated. The capital inflow that leads to a lower interest rate also leads to the exchange rate appreciation that is responsible for lower exports. Moreover, supply must equal demand, so that the third channel cannot be examined in isolation from the other two. We begin with a miniature model that illustrates the forces at work within the context of equilibrium in the goods market and the balance of payments. For illustrative purposes, the model is extremely simple. However, we argue that the model's implications generalize under a variety of extensions. After discussing the model, we record that the evidence is broadly consistent with the model, and then we quantify the effect on GDP growth of each of the three channels. In the quantification, we make only minimal assumptions, much less strong than those of the model (and even its generalizations).

4.1 A miniature model

The model is illustrative and is designed to capture the essence of the response to the capital inflows. The open economy, which can be thought of as either the United States or all non-Asian crisis countries, is characterized by two equations:

$$(1) \qquad Y^S(R\overset{+}{E}R) = DD(\overset{-}{r}) + NX(R\overset{-}{E}R)$$

$$(2) \qquad NX(R\overset{-}{E}R) + KA(\overset{+}{r},\overset{+}{\gamma}) = 0$$

where Y^s = supply = GDP, *DD* = domestic demand, *NX* = net exports, *KA* = capital account (net capital inflows), *RER* = real exchange rate, r = real interest rate, and γ = a balance of payments shift variable. The first equation represents goods market equilibrium, while the second represents balance of payments equilibrium. In equation (1), the supply of goods is written as a positive function of the real exchange rate. A real appreciation (rise in *RER*) implies that the prices of imported inputs fall, which has a positive supply effect. Supply is equated to demand, which is the sum of domestic demand and net exports. Domestic demand decreases in response to a rise in the real interest rate, and net exports decrease in response to a real exchange rate appreciation.

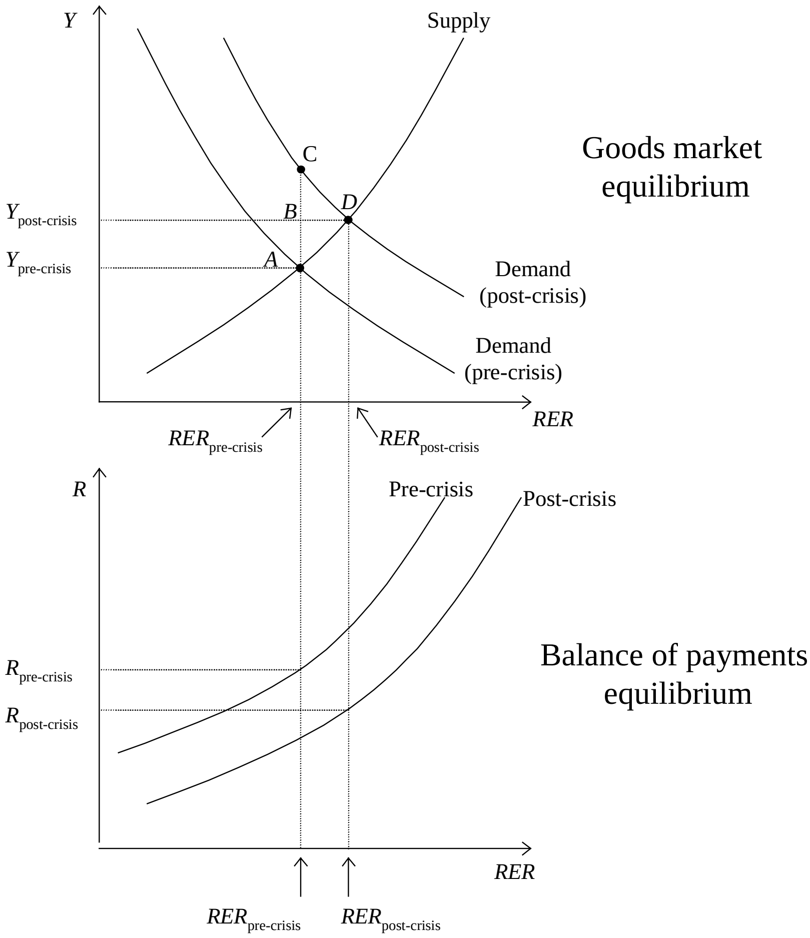
Equation (2) represents balance of payments equilibrium. Net exports plus net capital inflows must be equal to zero. Net capital inflows are written as a positive function of the real interest rate. They also depend on the shift variable γ, which corresponds to an (autonomous) demand for US (and other industrialized country) assets. We model the start of the Asian crisis as an increase in γ, that is, a desired shift in capital from the Asian countries to the United States and other industrialized countries. For our purposes, it is not important to know the exact cause of this desired reallocation of capital; we can think of the cause as a general decline in financial and macroeconomic conditions in the crisis countries.

This simple model is diagramatically represented in Figure 14. The top diagram represents goods market equilibrium. Output is on the y-axis and the real exchange rate is on the x-axis. The demand schedule is drawn for a given interest rate. The bottom diagram represents balance of payments equilibrium (equation (2)). The reallocation of capital to the United States (or non-Asian countries in general) – represented by an increase in γ – leads to a downward shift in the balance of payments equilibrium schedule. At a given real exchange rate, the new balance of payments equilibrium is reached at a lower interest rate. This lower interest rate leads to an increase in demand, shown by a rightward shift in the demand curve in the top diagram. Output increases and the real exchange rate appreciates. The figure illustrates the pre-crisis and post-crisis levels of output, interest rate and real exchange rate.

The figure also permits a clean decomposition of the domestic demand and net export demand effects. The distance *AC* captures the increase in domestic demand engendered by the lower interest rate, while *BC* captures the reduced net exports caused by the real appreciation (corresponding to a movement from *C* to *D* along the demand curve). The net effect on output is equal to the distance *AB* and is positive. This corresponds to the increase in supply as a result of the drop in the relative price of imported inputs (movement from *A* to *D* along the supply curve).

The model can easily be extended in two ways. First, it is likely that domestic demand depends positively on income $Y = Y^s$, while net export depends negatively on income. A rise in income raises

Figure 14: Diagrammatic representation of the model



AC = Rise in domestic demand due to lower interest rate
BC = Drop in net exports due to real appreciation
AB = Net positive effect on output

import demand, which lowers net exports. In that case $DD = DD(\overset{-}{r},\overset{+}{Y})$ and $NX = NX(\overset{-}{RER},\overset{-}{Y})$. Such an extension eliminates the clean decomposition of the two demand effects, but it does not change the conclusions. The reallocation of capital resulting from the increase in γ still leads to a decrease in the interest rate, a real appreciation, and a rise in output.

Another extension would be to include foreign income (and output) Y^*. As mentioned before, the capital outflow from Asia led to a recession in these countries, which led to a drop in US net exports. In order to appropriately include for Y^*, we need to model the Asian countries as well. The world now consists of the United States (or non-Asian countries in general) and the Asian crisis countries. The latter are denoted by an asterisk (*). The extended model is displayed in Box I. Three changes are noteworthy relative to the two-equation miniature model. First, there is an additional equation, which is the foreign goods market equilibrium condition (and the foreign interest rate is the third endogenous variable). Second, net exports depend on both domestic and foreign income, while domestic demand depends on domestic income. Finally, capital flows depend on the interest rate differential. One can easily check that this model generalizes the conclusions reached from the miniature model discussed above. The rise in γ still leads to a decrease in interest rates in the home country, real appreciation of the home currency and a rise in home output. The model now also has implications for the foreign country (the Asian crisis region). Its real interest rate will rise and output will decline.

Box I
A two-country equilibrium model

Domestic goods market equilibrium

$$Y(R\overset{+}{E}R) = DD(\overset{-}{r}\overset{+}{Y}) + NX(R\overset{-}{E}R, \overset{-}{Y}, \overset{+}{Y}^*)$$

Foreign goods market equilibrium:

$$Y^*(R\overset{-}{E}R) = DD^*(\overset{-}{r}^*, \overset{+}{Y}^*) - NX(R\overset{-}{E}R, \overset{-}{Y}, \overset{+}{Y}^*)$$

Balance of payments equilibrium:

$$NX(R\overset{-}{E}R, \overset{-}{Y}, \overset{+}{Y}^*) + KA(r \pm r^*, \overset{+}{\gamma}) = 0$$

4.2 Evidence on the three channels

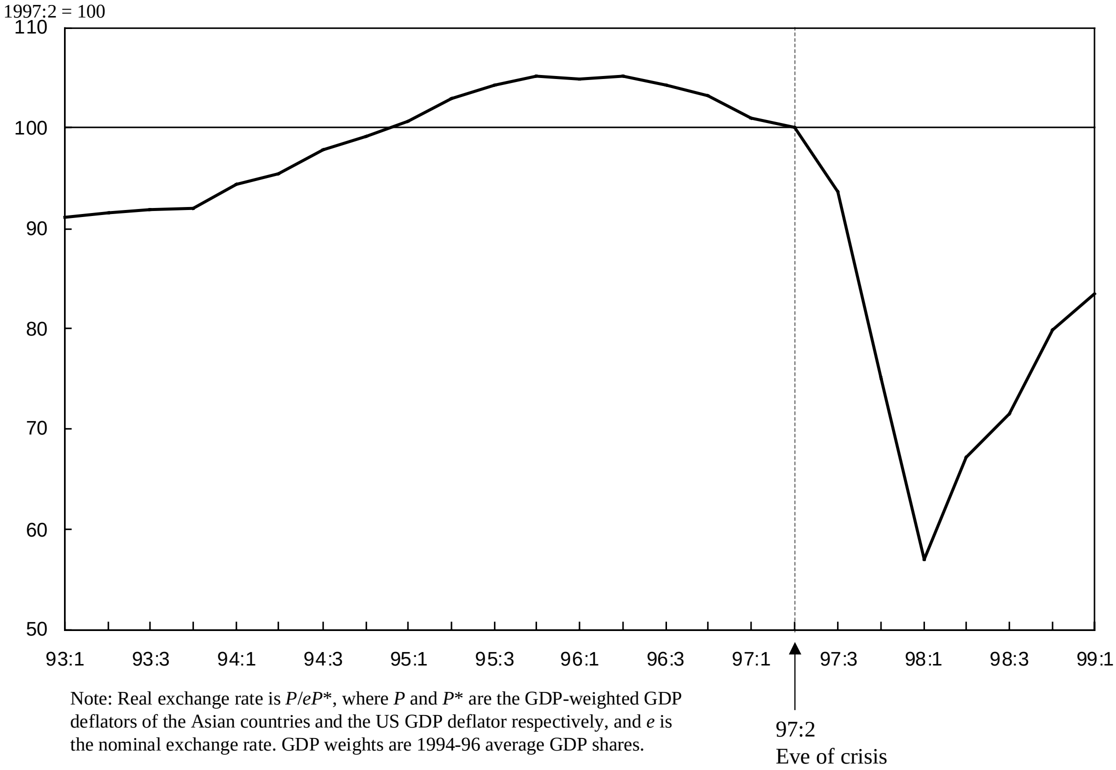
In this section, we examine several macroeconomic indicators that provide evidence on the three channels. Figures 15 to 21 show that the evidence is broadly in line with the model.

The negative trade channel is illustrated in Figures 15 and 16. Figure 15 shows the real exchange rate of the dollar against a GDP-weighted average of the Asia-4. We used GDP deflators as proxies for the price levels. The figure shows a 40% real appreciation of the dollar from the second quarter of 1997 to the first quarter of 1998. Together with the immediate and sharp recession in the Asia-4 following the crisis, the appreciation led to a large drop in net exports to the Asia-4 economies. Figure 16 shows that US merchandise net exports to the Asia-4 fell from about \$2 to 3 billion per quarter before the crisis to \$–5 to –7 billion per quarter soon after the crisis. Summing over the four quarters preceding the crisis (1996Q3–1997Q2) and over 1998, we find that net exports fell by about \$30 billion after the onset of the crisis. For a broader group of Asia-8 countries, which also includes China (mainland), Hong Kong, Malaysia and Singapore, US net merchandise exports fell by \$46 billion after the crisis. Figure 16 also shows that the United States was not alone. Net exports from Japan and Europe to the Asia-4 also fell considerably following the crisis.

Figures 17–19 provide evidence that the second channel was important. Figure 17 shows that, with the exception of very short-term rates, interest rates fell considerably following the crisis. The 30-year fixed mortgage rate fell by 150 basis points from the middle of 1997 to early 1998, followed by a further drop during the course of 1998 to reach its lowest level in 30 years. The yield on Moody’s Aaa-rated corporate bonds fell by a similar magnitude, while the 10-year government bond yield fell by even more. Figure 18 shows that the drop in mortgage rates lead to a sharp increase in mortgage refinancing. A significant fraction of the mortgages refinanced during 1998 involved cash-outs, increasing the overall size of the mortgage.

Our model implies that we would expect to see a drop in the contribution to GDP growth coming from net exports (channel 1), while we would expect to see a rise in the contribution to GDP growth from domestic demand. Figure 19 illustrates that this is exactly what happened. While the GDP growth rate in 1998 (Q/Q–4) remained unchanged at 4%, the contribution from domestic demand rose from about 4% pre-crisis to about 5% post-crisis. At the same time, the contribution from net exports fell from slightly negative to about –1%. Figure 20 shows that the United States was not alone as Europe underwent a similar response to the crisis. We have separated the Europe-6 from the United Kingdom.

Figure 15: Asia-4/US GDP-weighted real exchange rate



Note: Real exchange rate is P/eP^*, where P and P^* are the GDP-weighted GDP deflators of the Asian countries and the US GDP deflator respectively, and e is the nominal exchange rate. GDP weights are 1994-96 average GDP shares.

Figure 16: Net exports to the Asia-4

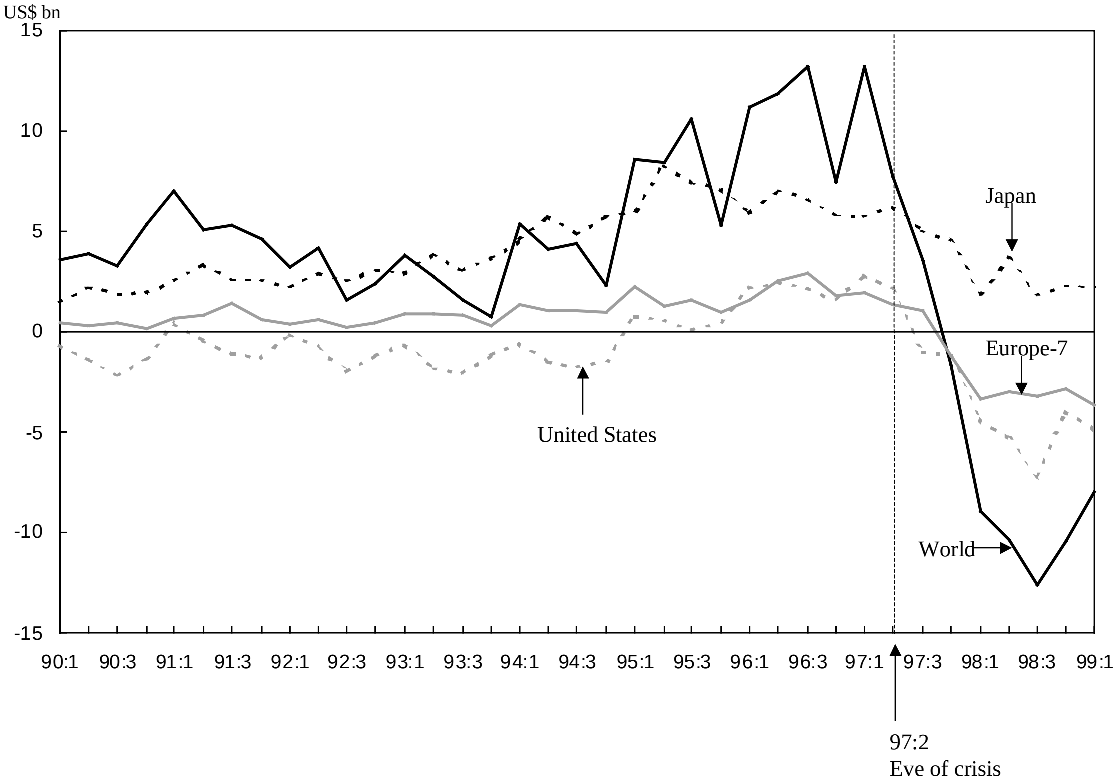


Figure 17: US interest rates

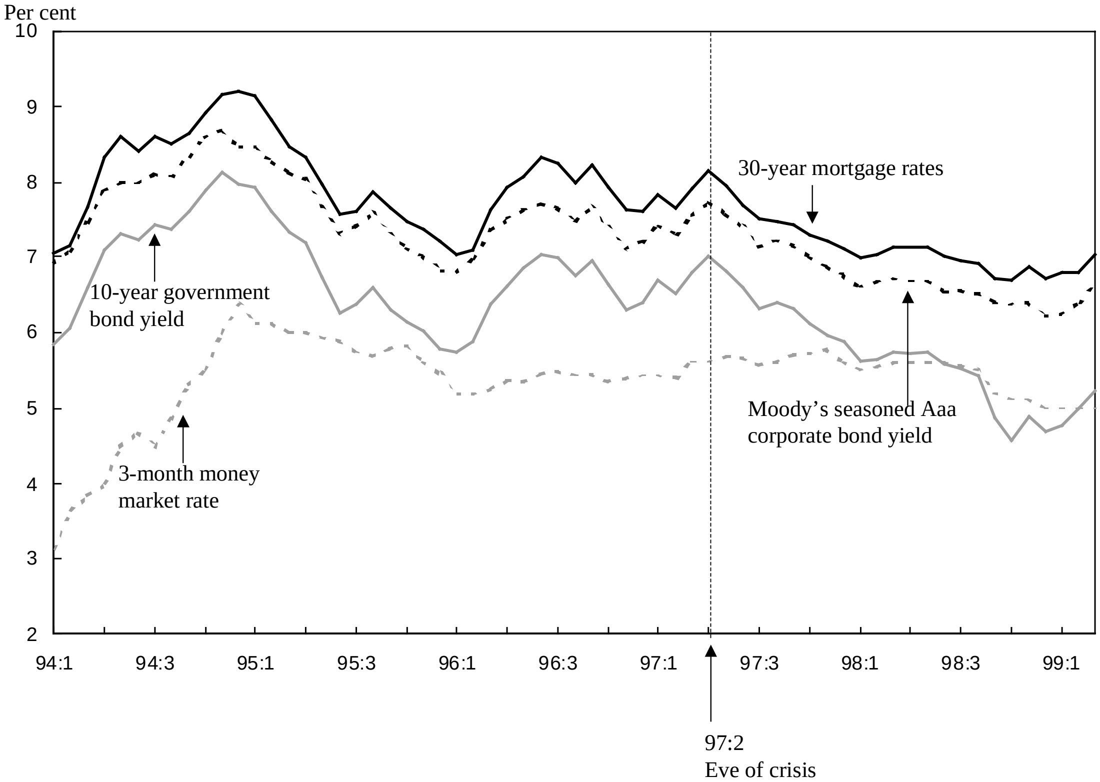
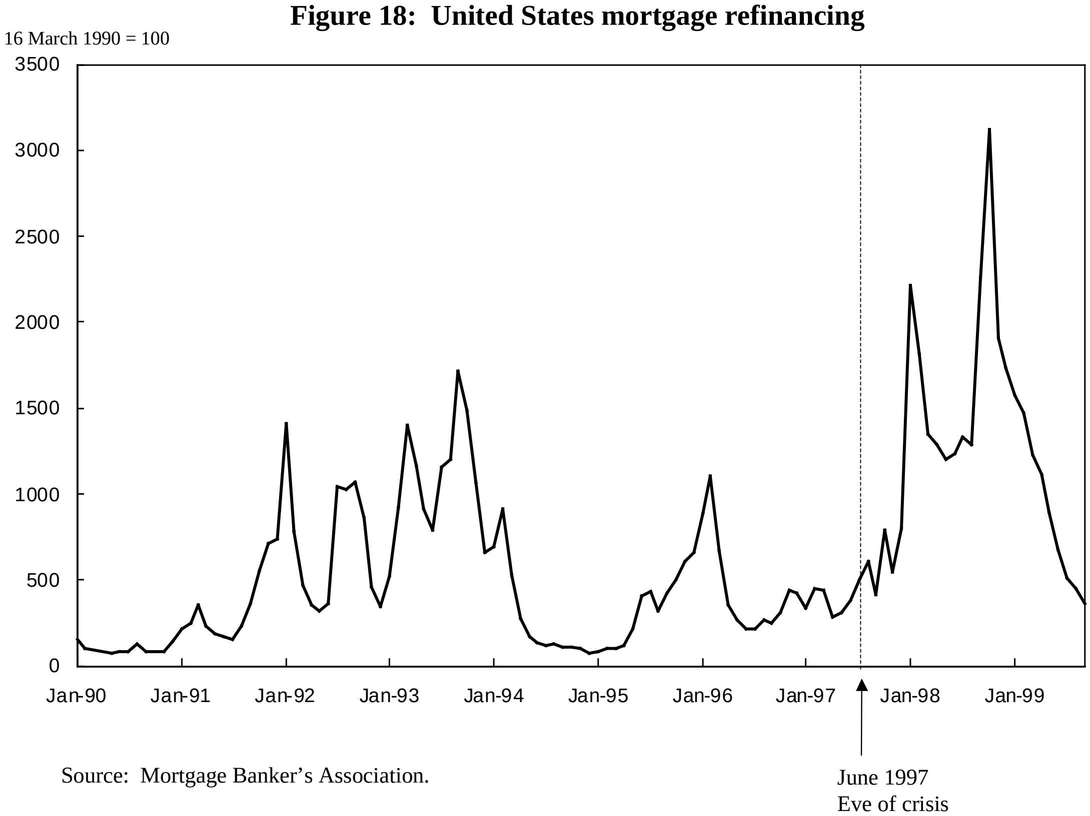


Figure 18: United States mortgage refinancing



Source: Mortgage Banker's Association.

Figure 19: Composition of US growth

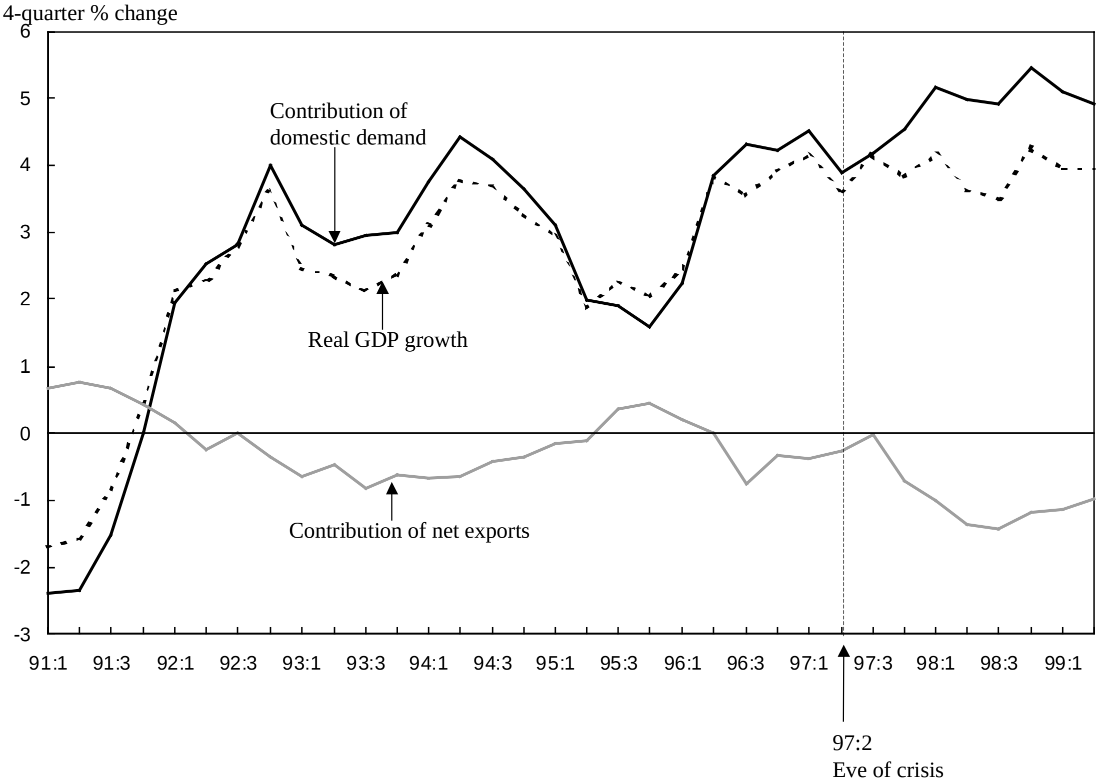
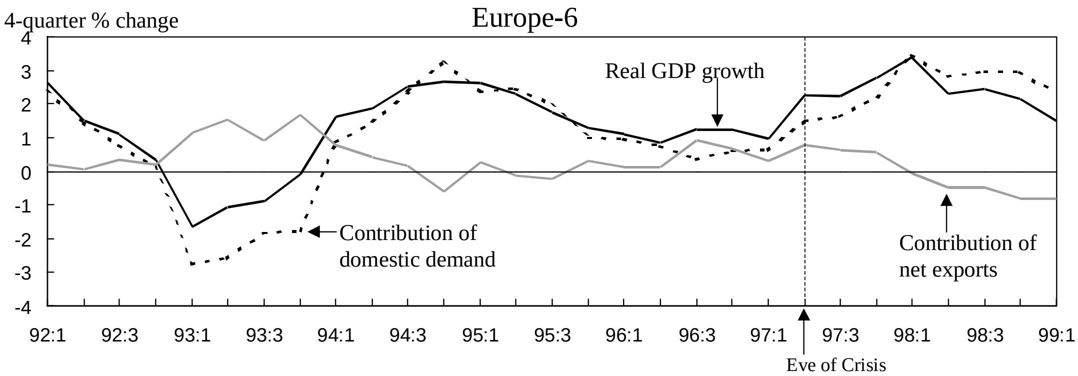
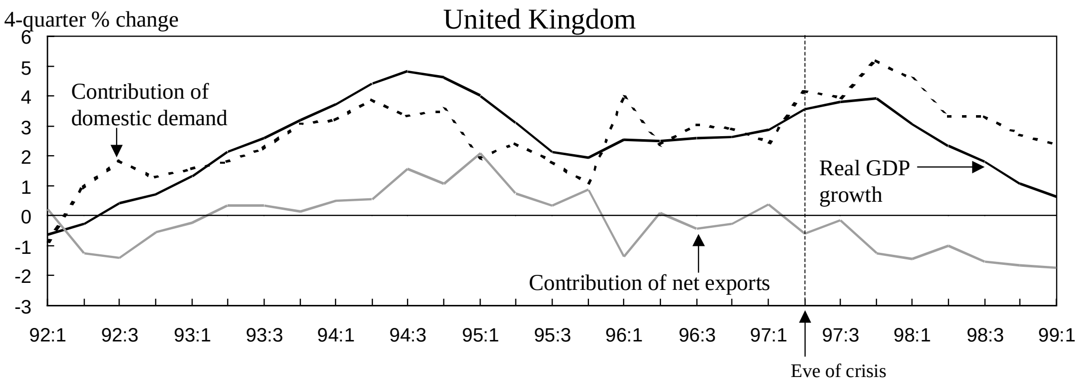


Figure 20: Composition of European Growth

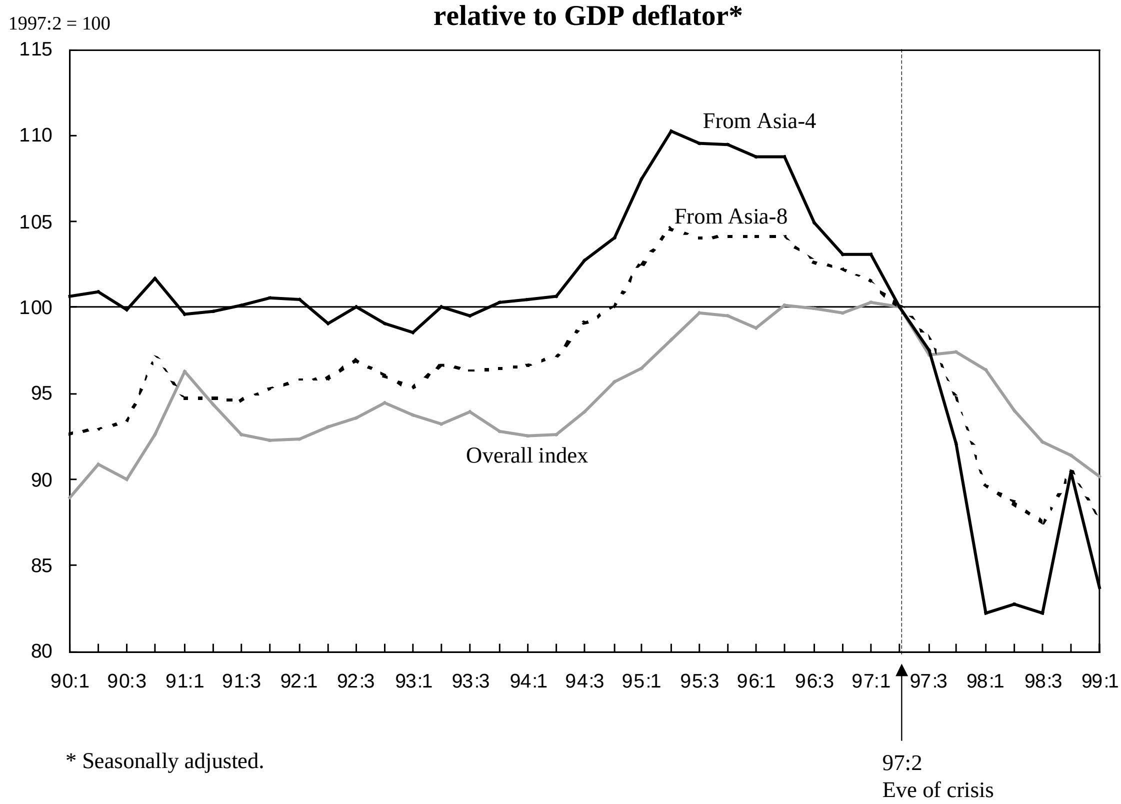




The United Kingdom is a special case because significant fiscal consolidation and a tightening of monetary conditions dampened domestic demand growth. For the Europe-6, we see that the contribution of domestic demand growth rose from about 1% pre-crisis to a level between 2% and 3% post-crisis. At the same time, the contribution of net exports to GDP growth fell from slightly below 1% to slightly above –1%.

The third channel depends on both the change in the relative price of imports (the reciprocal of the real exchange rate) and on the elasticity of supply with respect to the relative price of imports. Here, we provide evidence on the relative price of imports; the next section derives the elasticity of supply. Figure 21 shows the import price index for total imports, and for merchandise imports from the Asia-4 and the Asia-8.[10] All import price indices are shown relative to the US GDP deflator, and are indexed to 100 in 1997Q2. The Asia-8 index represents a broader view of the impact of the Asian crisis on US import prices. The import price indices show a sharp decrease for both sets of countries. From the pre-crisis period 1996Q3–1997Q2 to 1998, the relative import price index dropped by 18% for the Asia-4 and 12% for the Asia-8.[11]

Figure 21: Real US import price indexes, relative to GDP deflator*



* Seasonally adjusted.

4.3 Quantifying the three channels

We now attempt to quantify the effect on GDP growth of each of the three channels. In so doing, we impose only minimal assumptions, in contrast to the strong structure imposed by the model. We can estimate the trade effect without making any model-specific assumptions. By directly examining bilateral trade data, we can estimate how much the contribution to US GDP growth from net exports

---

10 We have proxied the US import price index from each Asian country by each country's overall export price index (expressed in US dollars).

11 These numbers are consistent with those reported in Barth and Dinmore (1999).

fell as a result of the Asian crisis. We do not need to know precisely what factors gave rise to the drop in net exports to the Asian crisis countries. In estimating the supply effect, we assume that firms maximize profits by choosing optimal levels of labor input and imported intermediate goods. To facilitate our calculations of the supply effect, we make three auxiliary assumptions. First, we hold the capital stock constant. This assumption is not very restrictive, because it simply reflects the fact that our analysis is short-term. Second, we assume that the real wage rate is constant. This implies that the labor supply schedule is perfectly elastic. We argue below that this assumption is not essential to our main findings. As long as the labor supply schedule is not perfectly inelastic we will obtain qualitatively similar results. Third, we make assumptions about the production technology; these are described in detail below. The essential assumption is that firms are profit-maximizing, so that output is not simply demand-determined.

We estimate the domestic demand effect as the residual. The difference between the supply effect and the trade effect equals the domestic demand effect. It would be difficult to calculate the domestic demand effect directly. For example, we would need to know the size of the increase in capital flows to the United States that can be traced to the crisis. We would need to know the effect of these inflows on the interest rate. We would need to know the elasticity of investment demand and savings demand with respect to the interest rate. To know the savings demand and investment demand elasticities, we would need to have a model of consumption behavior and of investment behavior, with its corresponding set of assumptions. Hence, by treating the domestic demand effect as the residual, we avoid making the large number of assumptions necessary to calculate it.

In computing the trade and supply effects, we consider both the Asia-4 countries and the broader set of Asia-8 countries. The advantage of looking at the broader set of Asia-8 countries is that we take into account spillovers of the crisis to some important neighboring countries. We do not consider indirect supply channels operating through oil prices or commodity prices, however. The recessions in the Asia-8 countries clearly had some negative effect on oil prices in 1998. These indirect channels would tend to raise the estimates of our supply effect.

We define the pre-crisis and post-crisis periods as we did above: 1996Q3–1997Q2 and 1998Q1–1998Q4. It is not appropriate to simply compare 1997 and 1998 because the crisis had already started in 1997. Another unattractive alternative would be to compare the four quarters before the crisis to the four following the start of the crisis (1996Q3–1997Q2 compared to 1997Q3–1998Q2), because the crisis did not fully take effect until 1998. As shown in Figure 16, it took two to three quarters for net exports to drop to their lower post-crisis level. As discussed in Section 2, the effect of the capital outflows on the current account of the Asian countries was initially buffered by IMF credit and a drop in reserve assets. The full adjustment of the current account did not take place until 1998Q1.

In computing the trade effect, we focus on merchandise trade. This is a reasonable approximation because 79% of total US trade in 1998 was merchandise trade, which is also considerably more volatile than services trade. The contribution to real GDP growth of net exports can be written as

$$\frac{P_X X}{Y}\frac{\Delta X}{X} - \frac{P_M M}{Y}\frac{\Delta M}{M} = \frac{\Delta(P_X X - P_M M)}{Y} - \left(\frac{P_X X}{Y}\frac{\Delta P_X}{P_X} - \frac{P_M M}{Y} - \frac{\Delta P_M}{P_M}\right)$$

where Y is nominal GDP, P_M and P_X are import and export price indices vis-a-vis the Asian countries, and X and M are quantities of bilateral exports and imports. The first term on the right-hand side measures the change in the nominal trade balance relative to GDP. The second term measures the price effects. The price effects are subtracted from the nominal trade effect to get the overall real trade effect. We approximate the US export price index to the Asian countries by the overall US export price index. The import price index is approximated by an import weighted-index of the Asian country export price indices.

Box II shows details of the firms' profit maximization problem that underlies our calculation of the supply effect. Firms maximize the difference between the value of gross output and costs. The variable costs are labor costs and the costs of imported inputs. We are interested in the effect of a decrease in intermediate input prices on supply. After computing the first-order conditions for imported inputs and labor, the supply effect can be written as:

(3) $$\frac{\Delta GDP}{GDP} = \frac{\beta}{1-\beta}\frac{\alpha}{\alpha-1}\frac{\Delta(P_M / P)}{P_M / P}$$

where β is the share of imported inputs in total production costs in the pre-crisis period and α is the share of labor income in domestic valued added. P_M/P is the price of intermediate inputs relative to the price of output. Real GDP is equal to gross output minus intermediate inputs, measured at pre-crisis price levels. We compute the change in the overall P_M/P as the merchandise import share from the Asia-4 or Asia-8 multiplied by the percentage change of P_M/P for the Asia-4 or Asia-8.[12] Notice that the supply effect is independent of the elasticity of substitution between imported inputs and domestic value added. The labor income share of GDP in 1997 was 58%, so we set $\alpha = 0.58$. We set β equal to US imports of intermediate and capital goods in 1998 (about 60% of total merchandise imports) divided by the sum of those imports and US GDP. This yields approximately 0.06.

Box II

Firms' decision problems:

Maximise $P\bar{Y} - WL - P_M M$

where:

$\bar{Y}$ = gross output

L = labor

K = capital = constant

M = imported intermediates and imported capital goods

P = price of imported inputs

P_M = price of imported inputs

$\bar{Y} = F(\phi(K, L), M)$ (production function)

$\phi(K, L)$ = Cobb-Douglas index of K and L (labor share = α)

$F(.,.)$ = CES index with elasticity of substitution ϵ.

The results of these computations are reported in Table 2. If we interpret the Asian crisis broadly as corresponding to developments in the Asia-8 countries, US GDP fell by 0.8 percentage points as a result of a drop in net exports to those countries, while it rose by 1.0 percentage points as a result of the increase in domestic demand. The net effect, which is also the supply effect, is +0.2 percentage points of GDP. The numbers are slightly smaller for the Asia-4. Our supply effect calculations suggest that the net effect of the Asian crisis is small, but positive.

These results do not change in a major way if labor supply is not perfectly elastic. In this case, the increased demand for labor (which results from lower prices of imported goods) leads to a rise in real wages. In the extreme case where labor supply is completely inelastic, the supply effect is zero. While the lower prices of imported inputs lead to an increase in demand for imported inputs, which raises gross output, domestic value added remains unaltered because both the capital stock and labor input are unchanged. In general, when labor supply's elasticity is finite, the supply effect will be somewhere between 0% and 0.2%.[13]

Our findings correspond well with Figure 19. It shows that real GDP growth remained virtually unchanged following the crisis. The negative effect from lower net exports was almost exactly offset

---

12 We approximate P with the GDP deflator, as in Figure 15. This is not exactly correct because P is the price of gross output. But it gives a very close approximation as β is quite small.

13 As noted earlier, we abstract from indirect supply effects, such as those resulting from oil prices. If the decline in oil prices in 1998 were entirely attributable to declining demand in the Asia-8 countries, then the supply effect would be considerably larger, close to 1.0 percentage points of GDP.

by the rise in domestic demand. The increase in the contribution of domestic demand to GDP growth from the pre-crisis to the post-crisis period (Figure 19) was about 1.0%. Hence, the Asian crisis could have accounted for all of the increase in US domestic demand.

Table 2
Growth effect of Asian crisis

	Asia-4	Asia-8
Trade effect	–0.5%	–0.8%
Domestic demand effect	+0.6%	+1.0%
Total effect	+0.1%	+0.2%

Notes: The table reports the contribution to GDP growth of lower trade and higher domestic demand as the result of the Asian crisis, as well as the total effect on GDP growth (which is also the supply effect). Results are reported both when thinking of the Asian crisis as narrowly associated with four countries: Korea, Thailand, Indonesia and the Philippines (Asia-4) and when it is associated with a broader set of eight countries that also includes Hong Kong, Malaysia, Singapore and China (mainland).

Other explanations have been put forward for the increase in US domestic demand during the Asian crisis. However, we believe that such alternative explanations are less plausible, particularly to the extent that they relate to US-specific developments. For example, it has been pointed out that the US stock market rise could be responsible for the recent surge in US consumption. It has also been suggested that US domestic demand increased in response to the new productivity revolution, which is ushering in an era of permanently higher GDP growth rates. Both of these stories are specific to the United States, because the continental European stock market is much smaller by comparison, and Europe is not undergoing such a productivity revolution. Any US-specific increase in domestic demand unrelated to the Asian crisis should have led to an increase in US interest rates, particularly relative to those in Europe and Japan. Moreover, we should have seen an exchange rate appreciation against the euro and the yen. Our earlier evidence showed that these events did not occur. In addition, we showed that the increase in the contribution of domestic demand to GDP growth in Europe was of similar magnitude to that for the United States. That this pickup in domestic demand on both sides of the Atlantic also occurred in exactly the same time period strongly suggests a causal link to the Asian crisis.

5. Conclusion

In the 1990s, many emerging market countries facilitated access for foreign investors to their financial markets by liberalizing controls on international capital flows. This has had benefits for both the emerging markets and for investors from industrialized countries. But there have also been risks associated with the increased exposure of foreign investors to these new markets, because capital inflows can be easily reversed in a short period of time. Assessing the causes of the crisis and the consequences for the crisis countries themselves has been the focus of much of the literature on the Asian crisis. In this paper we shift the focus, examining the implications for industrialized countries, and for the United States in particular, of such far away economic crises.

While early in the crisis the negative trade effects for industrialized economies were emphasized, it soon became clear that the trade channel was not the only transmission channel. By definition, a capital outflow from Asia is a capital inflow somewhere else. Capital inflows can finance an increase in domestic demand, which leads to an increase in GDP. One of our goals in this paper, therefore, has been to follow the trail of money out of Asia in order to ascertain its final destination. We have found it difficult to follow the trail very far, and to identify exactly how much ended up in the United States. We also found that large errors and omissions in the US balance of payments complicate the documentation of capital inflows to the United States.

Several stylized facts do emerge though:

1. The Asian crisis countries experienced net capital outflows close to $100 billion from the start of the crisis to the end of 1998.
2. The counterparties to the Asian outflows were essentially BIS reporting country banks.
3. About half of the outflows went to offshore center banks.
4. About half of the outflows went to banks whose nationality was neither US, Japanese nor European.
5. Very little money reached the United States directly from the crisis countries or through the offshore centers.
6. Most of the outflows from the Asian crisis countries, as well as from Japan, did eventually reach both the United States and Europe, probably through channels other than banks.

These facts highlight the importance of banks as the initial propagation mechanisms of the Asian crisis, as well as the "roundaboutness" of the banking flows. One extension for future research is to explore why banks played such a role.

The second goal of the paper was to analyze and quantify the short-run effect on US GDP growth. We identified three channels through which US growth was affected. First, the recessions in the Asian countries and depreciated Asian currencies imply fewer US exports and more US imports. Second, the lower US interest rates that are the result of the increased inflows imply greater domestic demand. Third, appreciation of the dollar implies lower prices for imported intermediates and imported capital goods, reducing the cost of production. Our calculations that quantify these effects suggest that the negative trade response is –0.8% of GDP, while the positive supply response is +0.2% of GDP. These two responses imply that the domestic demand response is about +1.0% of GDP. Thus, the overall effect on the US economy in 1998 is about +0.2% of GDP, or $15–$20 billion.

Going forward, as the Asian economies recover we can expect these effects to go in the opposite direction. If our findings are correct, however, a reversal of capital flows to the Asian countries will generate only a small net effect on US growth. However, it could generate large compositional effects on domestic demand and net exports.

Appendix

Figure 1: Sum across Korea, Thailand, Indonesia and the Philippines (henceforth known as the "Asia-4") of the "financial account" as reported by the IFS. The IFS did not yet report the Korean financial account in 1998Q4, so the "financial account" from McGraw-Hill's DRI Asia CEIC database is used for Korea.

Figure 2: Sum across the Asia-4 of "portfolio investment (liabilities +assets)", "direct investment abroad + direct investment in rep. econ =", and "other investment (liabilities + assets)" in the IFS. Due to missing 1998Q4 Korean data, the CEIC database is used to complete the "balance of direct investment", "balance of portfolio investment", and "balance of other investment" series.

Figure 3: Exchange rate adjusted flows, assets minus liabilities (including non-bank), as reported in the BIS block M database. Vis-à-vis area is the Asia-4 and the reporting area "grand total" of BIS reporting countries.

Figure 4: Exchange rate adjusted flows, assets minus liabilities (including non-bank), as reported in the BIS block M database. Vis-à-vis area is the Asia-4, while reporting areas are Japan, Offshore, United States + IBFs and Europe-7 = United Kingdom + Germany + France + Italy + Netherlands + Spain +Switzerland (henceforth known as the "Europe-7").

Figure 6: The top chart shows the stock of total assets vis-à-vis the Asia-4 with geographical origin of a bank being the reporting area. BIS block M is the source. The bottom chart also shows the stock of total assets vis-à-vis the Asia-4, but by nationality of ownership. These data come from the publication "The BIS Consolidated International Banking Statistics". Due to data unavailability, Switzerland is left out of the Europe series in the bottom chart.

Figure 7: "Financial account" series are the same as that from Figure 1. Other series: sum across the Asia-4 of "reserves and related items" and "current account" as reported by the IFS. The IFS did not yet report the Korean financial or current account in 1998Q4, so 1998Q4 data for the Korean current account come from Bank of Korea External Economic Indicators, Table P.F.2b, while "changes in reserve assets" from the CEIC database was used for Korea for that quarter.

Figure 8: With some exceptions in the most recent quarters, current account balance data for Germany, France, the Netherlands, the United Kingdom, Switzerland and Spain are from the BIS; Italian data are from the Bank of Italy; Japanese, US, Korean, Philippine, Thai and Indonesian data are from the IFS. The exceptions are: Spanish current account in 1999Q1 is from Bloomberg; Korean numbers for 1998Q4 and 1999Q1 come from JP Morgan International Data Watch, as does the Indonesian value for 1999Q1. Data from the BIS are converted to US dollars using period average exchange rates. All series are seasonally adjusted using the X11 additive filter in Eviews 3.0.

Figure 9: The "net bank lending" series is the same as in Figure 4. The "net portfolio flows" series is derived from Treasury International Capital (TIC) data. Long-term net sales by foreigners to US residents are calculated from the TIC table "US Transactions with Foreigners in Long-Term Securities". Short-term treasury obligations from the TIC table "Liabilities to Foreigners Reported by Banks in the United States" are also included. Quarterly data are calculated using monthly sums.

Figure 10: These data are exchange rate adjusted flows, assets minus liabilities (including non-bank), as reported in the BIS block M database. The top chart is the United States + IBFs reporting vis-à-vis all BIS reporting countries, while the bottom chart is the United States + IBFs reporting vis-à-vis Japan, Offshore and the Europe-7.

Figure 11: US "financial account", "current account" and "net errors and omissions" are from the IFS.

Figure 12: Exchange rates are monthly averages of the daily BIS series QBCAXM02 and QBBAJP02.

Figure 13: All data are from the European Central Bank's website at http://www.ecb.int/stats/mb/eastats.htm. The top chart data are three-month deposit rates for the

United States, Japan and euro area from Table 3.1. The bottom chart data are 10-year government bond yields for the United States, Japan and euro area from Table 3.2.

Figure 15: Quarterly average exchange rates for the Asia-4 are from the IFS. GDP deflators are calculated using nominal and real GDP series from the CEIC database. After indexing all series to 1997Q2 = 100, a GDP-weighted (1994–96 average GDP shares) average of the real exchange rates yields the Asia-4/US real exchange rate.

Figure 16: Data are from the IMF's Direction of Trade Statistics database. Asia-4 countries are the primary country, i.e. Asia-4 countries report data on exports and imports, while secondary countries are World, the United States, Japan and Europe-7 countries. To construct each series, the quantity (net exports * –1) was summed across the Asia-4 countries and across the Europe-7.

Figure 17: Three-month money market rates and 10-year government bond yields come from the European Central Bank's Euro Area Statistics Monthly Data, Tables 3.1 and 3.2, respectively (see Figure 13). The Moody's Seasoned Aaa Corporate Bond Yield series and 30-year mortgage rates series (Contract Rates on Commitments: Conventional 30-Yr Mortgages, FHLMC (%)) are both from Haver Analytics' USECON database. The money market rate is an end-of-period rate, and the other interest rates are monthly averages of daily rates.

Figure 18: This series is the refinancing index from the Mortgage Bankers' Association weekly survey. Data are seasonally adjusted and weekly observations have been converted to monthly averages.

Figure 19: All data are from USECON. Contribution of domestic demand = [nominal DD(Q-4)/nominal GDP(Q-4)] *Real DD growth Q/Q-4. Nominal domestic demand is the sum of the C, I and G (consumption, investment and government) series. Real domestic demand is the sum of the CH, IH and GH (1992 chain-type dollar of the C, I and G series) series. Nominal GDP is simply the series "GDP". The "Real GDP growth" series is GDPH (seasonally adjusted, 1992 chain-type dollar). The "Contribution of net export" series is the difference between "Real GDP growth" and "Contribution of domestic demand".

Figure 20: For the top chart, contribution of domestic demand = (sum nominal domestic demand (Q-4) across Europe-6/sum nominal GDP(Q-4) across Europe-6)*(Europe-6 real domestic demand growth (Q/Q-4).

In the above formula, nominal domestic demand and nominal GDP series are from the BIS database, where nominal domestic demand is reported in local currency and Nominal GDP is reported in dollars. Nominal domestic demand is converted to dollars (for the purpose of summing) using the period-average quarterly exchange rates from the IFS. Real domestic demand growth for the individual Europe-6 countries is from the following BIS series and corresponding countries: Italy (RHWBIT01), France (RHWBFR01), Germany (RHWBDE01), Switzerland (RHWACH01), the Netherlands (RHWBNL01), and Spain (RHWBES01). The BIS did not yet report Italy's 1998Q4 real domestic demand growth, so Bloomberg (original source is ISTAT) provided the data. Europe-6 real domestic demand growth for each quarter is constructed as the weighted average (a country's weight was the individual country's nominal domestic demand four quarters ago) of the individual countries' real (Q/Q-4) domestic demand growth rates.

Europe-6 real GDP growth is calculated as the weighted average (a country's weight was the individual country's nominal GDP four quarters ago) of the individual countries' real (Q/Q-4) GDP growth rates. The nominal GDP data used in the weighting are the same BIS series used in the construction of "contribution of domestic demand" (see above). The individual countries' real GDP data are from the following BIS series and corresponding countries: Italy (RHGBIT01), France (RHGBFR01), Germany (RHGBDE09), Switzerland (RHGACH01), the Netherlands (RHGBNL01), Spain (RHGBES01). Italy's 1998Q4 real domestic demand is from Bloomberg (original source is ISTAT).

For the bottom chart, the United Kingdom's contribution of domestic demand = [nominal DD(Q-4)/Nominal GDP(Q-4)] *real DD growth Q/Q-4. In the above formula, nominal domestic demand and nominal GDP series are from the BIS, where nominal domestic demand is reported in pounds sterling and nominal GDP in dollars. Nominal domestic demand is converted to dollars (for the purpose of summing) using IFS quarterly period average exchange rates. Real domestic demand growth is from the BIS series RHWBGB01.

UK real GDP growth is from the BIS series RHFBGB01.

In both charts in this figure, the "contribution of net exports" series is the difference between "real GDP growth" and "contribution of domestic demand".

Figure 21: US import price indices from the Asian countries are approximated using export price indices of the Asian countries (from Oxford Economics) in dollar terms. Indices are deflated using the US GDP deflator. After calculating real import price indices from the eight Asian countries, 1995 US import shares yield weighted averages for the Asia-4 and Asia-8.

Bibliography

International Monetary Fund, *International Financial Statistics.* Various issues.

Barth, Marvin and Trevor Dinmore (1999): "Trade Prices and Volumes in East Asia Through the Crisis". Board of Governors IFDP, No. 643, August.

The response of financial markets in Australia and New Zealand to news about the Asian crisis

Luci Ellis and Eleanor Lewis[1]

1. Introduction

As financial markets become more integrated, shocks can be transmitted quickly between them. In times of market turmoil, this implies that the effects of negative shocks might be felt in markets far removed from the originating market. In this paper, we investigate the spillover of financial-market volatility, specifically the impact of recent news from Asia (Korea, Thailand and Indonesia, as well as Malaysia and the Philippines), on financial markets in Australia and New Zealand. We examine the initial impact of key events and announcements in the Asian crisis period and the spillover of these effects, as measured by both financial prices and proxies of their volatility.

We find that realisations of news – both positive and negative – that came out of Asia during the crisis clearly had repercussions for financial markets that were not directly affected by these events. But these effects must be put in perspective: developments in the US market generally had a much greater influence on price movements and volatility than cross-market shocks originating in the Asian crisis economies. This result is in line with previous work on the importance of overseas returns in Australian markets (Kortian and O'Regan (1996)). We also find evidence indicating that stock markets reacted to developments in Asia with a lag, after the United States reacted, rather than reacting directly to the news itself.

Our results indicate that the volatility in Australian and New Zealand financial markets in late 1998 – which we term the "world crisis" period – was generally as great as or greater than in the 1997–98 period, when the main news events of the Asian financial crisis occurred. We also find that the apparent spillover of financial market returns from Asia to Australia and New Zealand was small and – for some asset classes – *smaller* in the Asian crisis period than previously. This implies that the shocks originating in Asia were less important for Australian and New Zealand markets than were the global "common" shocks affecting all of these markets simultaneously.

The evidence suggests that the *volatility* seen in Australian and New Zealand markets was not affected by the different stances of monetary policy, or the differing natures of the monetary policy regimes in the two countries. The effects of developments in Asia on volatility in Australian and New Zealand financial markets were remarkably similar, despite the distinctly different methods used to conduct monetary policy over that period. These results reflect the short-run measure of volatility that we adopt in this paper, however. The *levels* of the financial market variables in Australia and New Zealand display differing profiles: there were large divergences in stock and bond prices over the period. On the other hand, the exchange rates of the two currencies against the US dollar moved together, reflecting that these currencies are generally traded as a bloc.

This paper draws on the literature on contagion (Eichengreen et al. (1996) is a key empirical paper; see Dungey (1999) for a survey). Calvo and Mendoza (1999) show that contagion of financial market volatility might increase as world markets become more integrated. In certain circumstances, the costs of gathering and analysing information about unfamiliar foreign markets may outweigh the perceived benefits. This can result in investors choosing to act on the basis of rumours unrelated to market

[1] Luci Ellis is a member of the Economic Analysis Department and Eleanor Lewis of the International Department. We are indebted to colleagues at the Reserve Bank of Australia and to Mardi Dungey for invaluable comments and suggestions. We are also grateful to Adam Cagliarini for technical advice and Clare Padua for assistance with the data. Any errors are ours alone. The opinions expressed in this paper are those of the authors and should not be attributed to the Reserve Bank of Australia.

fundamentals, instead of on complete information. In addition, fund managers may face incentives that encourage herd behaviour in portfolio allocation decisions. Both of these effects can result in contagion of financial volatility from markets in one country to those in other countries.

Masson (1998) has defined contagion as the portion of financial market volatility that cannot be explained by normal factors such as domestic fundamentals and global common shocks. However, much of the contagion literature focuses on the propagation of exchange rate crises and does not deal explicitly with the transmission of volatility outside crisis periods (Dungey and Martin (1998) is an exception). In this sense, this paper has more in common with the literature on "meteor showers and heat waves", which studies geographic (time zone) patterns in the volatility of particular securities (Engle et al. (1990); Fleming and Lopez (1999) is a recent example). We seek to identify the effect of "meteors" – as measured by news events or volatility in one market – on returns and volatility in other markets.

Previous work on the effects of macroeconomic "news" on Australian financial market prices and volatility has focused on announcements made at pre-scheduled times, such as Australian CPI releases (Campbell and Lewis (1998) and Kim (1996)). In these cases, the content of an announcement may be a surprise, but its timing is not. Therefore, it is possible for market participants to plan their contingent trading strategies in advance. If the timing of an announcement is not known in advance, however, traders have less opportunity to plan for its effects. Previous empirical work for other countries has suggested that unscheduled announcements tend to have more persistent effects on financial returns than do scheduled announcements (Almeida et al. (1998)), although the difference can be measured in hours. In general, studies of this kind examine the impact of economic announcements on "own" financial markets. The present paper, however, focuses on the effects of unscheduled (though potentially anticipated) announcements relating to one group of countries on the financial markets of other countries.

The paper proceeds as follows. In Section 2, we discuss the reasons why financial markets in Australia and New Zealand might have been affected by the financial crisis in Asia. We also discuss our measure of news events and the financial market data to be analysed. Section 3 contains the empirical evidence on the response of financial markets in Australia and New Zealand to these news events, in terms of both volatility and price movements. In Section 4, we examine whether the spillover of financial market returns is greater in times of crisis than in more normal times, using results from vector autoregressions (VARs). Section 5 provides a brief conclusion.

2. Motivation and data

2.1 Why Australian and New Zealand financial markets might be affected

There are a number of reasons why negative events relating to the Asian financial crisis might be expected to have a negative effect on financial markets in countries such as Australia and New Zealand. Firstly, to the extent that financial crises in some countries result in a generalised increase in uncertainty in world financial markets, we should expect increased volatility in financial markets in non-crisis countries, which usually results in lower returns.

Secondly, the Asian crisis countries are important markets for Australian and New Zealand exports. As such, a pronounced recession in the crisis countries might be expected to have a negative effect on activity in Australia and New Zealand via the current account; these expectations would then flow through to financial market returns.[2]

Thirdly, some market participants might have factored in some possibility – however remote – that contagion of the crisis could have spread as far as Australia and New Zealand, perhaps relating to financial institutions' debt exposures to the crisis countries.

[2] This vector of contagion is essentially the economic linkages model of Lowell et al. (1998).

Finally, even if financial market participants do not expect that countries such as Australia and New Zealand will experience financial crises, they may expect that portfolio rebalancing behaviour could result in sharp declines in asset markets of countries with unrelated fundamentals. Kaminsky and Schmukler (1999) describe how market participants, in responding to a crisis in country A by selling country-A assets and buying country-B assets, may rebalance their portfolios by selling country-C assets, where country C is similar to country B. This ensures that the share of B and C assets in the portfolio remains at the desired level. This results in an apparent contagion of the crisis from country A to the unrelated country C. The effect is also consistent with the portfolio adjustment model of contagion in Lowell et al. (1998). In addition, the effect might be compounded if there is a significant number of uninformed traders in the market, as they may also sell country-C assets if they interpret the sell-off as reflecting a change in fundamentals.

The factors listed above could explain some co-movement between Asian financial markets and those in Australia and New Zealand. On the other hand, there may be reasons for Australian and New Zealand markets to move in the opposite direction to their Asian counterparts. If a financial crisis in one region caused overseas investors to repatriate or otherwise reallocate their funds, it is possible that markets such as Australia and New Zealand could have received them, putting upward pressure on asset prices in those countries. That is, Australia and New Zealand could have been country B, not country C, in the portfolio rebalancing scenario of Kaminsky and Schmukler (1999).

Further reactions to crisis events may occur, related to the actual or expected response by monetary policymakers. For example, if the authorities raise short-term interest rates in response to an exchange rate depreciation – or market participants expect that they will do so – this may result in a fall in stock prices and movements in long-term bond rates.

2.2 The impact of news on financial markets

A large literature exists on the impact of macroeconomic news on financial market prices sampled at high frequencies (Campbell and Lewis (1998), Fleming and Remolona (1997), Almeida et al. (1998), Kim and Sheen (1998) and Kim (1999) are some recent examples).

One distinction between most of this "event study" literature and the present paper is that the former generally examines the effects of news events on financial markets in the country in which the news originated. We focus on the effects of news on third-country markets. In addition, most of the previous literature examines the effect of official macroeconomic data releases, which generally have prescheduled release dates and times. Exceptions to this are releases of German macroeconomic data, which do not follow a predetermined schedule. In this case, market participants are less likely to be able to plan reaction strategies upon the release of the data. Almeida et al. (1998) find that the response of the US dollar/Deutsche mark bilateral exchange rate to German releases is somewhat more drawn out than the response to US releases, which are pre-scheduled (although the difference can be measured in hours).

The set of news events we consider goes even further than this, however. Although the precise timing of German macroeconomic releases is not known in advance, they are approximately regular. So although market participants may not know the exact timing of the German CPI release, they know that a release will occur each month. By contrast, news events during the Asian financial crisis were not always predictable. This would tend to increase the "surprise" value of news about the Asian crisis, relative to the surprise value embodied in regular releases of macroeconomic data.

Limitations of the available data, described in the next section, prevent us from examining the response of Australian and New Zealand financial markets to news at ultra-high frequencies of hours or minutes. Also, since we do not have information on the times that most of the news events occurred, we are restricted to examining news effects on a daily frequency.

Asian time zones largely overlap the Australian and New Zealand domestic trading zones. We would, therefore, expect that in most cases the reaction of Australian and New Zealand markets would begin on the same day that the Asian news events occurred. There will be some instances, however, in which the news events in Asia occurred after the market closes in Australia and New Zealand, and so the reaction will have occurred on the following day.

2.3 Identifying the timing of news events

The first step in assessing how news about the Asian financial crisis affected other countries' financial markets is to identify the events that constitute news. We use a combination of two pre-existing chronologies, one from the BIS and the other from the IMF (BIS (1998) Table VII.6, page 131; IMF (1998) Box 2.12, page 49), as well as the RBA's daily market reports. A table listing the events from these sources is shown in the Appendix. It should be noted that in some cases the dates cited in the IMF chronology differ from other IMF papers (e.g. IMF (1999)). Where possible, we verified the dates using newswire stories and other sources. The IMF and BIS chronologies end in June and March 1998 respectively; we extended the chronology in this paper to end-August 1998 using the RBA's daily market reports.

Positive news will have the opposite effect on markets to negative news, suggesting that we should distinguish between events that are considered "good" or "bad" news. We classify events relating to agreements between international agencies and crisis countries, announcements of rollovers of debt and certain reforms as "good news"; all other news events listed in the Appendix are considered to be "bad news". The classification of events as positive or negative is shown in the right-most column in the table. Our listing is similar to the classification used by Kaminsky and Schmukler (1999), based on the chronology compiled by Roubini (1999), and to that of Baig and Goldfajn (1998), compiled from newswire stories.[3]

Kaminsky and Schmukler (1999) report that days on which some of the most volatile movements in Asian financial markets occurred were not necessarily associated with specific news events relating to the crisis. There are a number of possible explanations for this. Firstly, markets might react to cumulations of news, so that a seemingly "small" or unimportant news event can engender a greater response if it follows a series of news events (the "straw that broke the camel's back" effect). Secondly, there may be some herding behaviour by traders, so that sudden changes in financial prices can occur even in the absence of significant news. Thirdly, the news events considered may be less relevant to asset markets than the trading strategies used by market participants. To maximise returns from these trading strategies, it may be necessary to take advantage of particular market conditions, such as thin volume, which may not occur on news event days.

2.4 The financial market data, episodes and volatility

The data used to measure financial market returns and volatility for Australia and New Zealand in this study are: the broad indices of stock prices – the All Ordinaries Index (AOI) for Australia and the NZSE40 for New Zealand; bilateral exchange rates for the Australian and New Zealand dollars against the US dollar; and the prices on futures contracts for Australian and New Zealand 10-year bonds, which trade on the Sydney Futures Exchange (SFE) and the New Zealand Futures and Options Exchange (NZFOE).[4]

We use daily market-close data for stock prices and bond futures prices, and 4 pm (AEST) readings for the bilateral exchange rates. Given these data series, we need to derive an appropriate measure of volatility: for daily data, the usual approach is to take the absolute value of daily percentage changes in prices (returns), or squared percentage changes. To avoid introducing spurious autocorrelation into our measure of financial market volatility, we do not use measures such as rolling standard deviations of

---

3 Although this classification is somewhat arbitrary, it did not seem to be crucial to our results.

4 The bonds data are for the "next" contract to be delivered, which is a very close substitute for the underlying spot instrument, i.e. physical 10-year bonds. The markets in these instruments on the futures exchanges are deep and liquid and provide reliable price readings. These markets are generally considered to be more liquid than those for the corresponding physical securities.

daily returns. Although the daily series will be considerably noisier than series that incorporate information from a run of days, their time-series properties will be more informative.

An alternative approach would be to use the diffusion-theoretic measure of daily realised volatility, which can be calculated (to a close approximation) as the daily summation of squared *intra*day returns (Andersen et al. (1999)). It is not clear, however, that volatility within the day is the appropriate measure of interest to policymakers. In any case, one of the principal attractions of this alternative measure of realised volatility is that some transformations of it may be normally distributed; this did not seem to be the case for the intraday data available to us. This could, at least in part, reflect that this intraday data set had a large number of missing observations.[5]

We examine financial market behaviour in Australia and New Zealand from the beginning of 1994 to the end of August 1999. We compare times of crisis with other times by dividing our sample into four sub-periods or episodes: "pre-crisis" – from 1 January 1994 to 30 April 1997; "Asian crisis" – from 1 May 1997 to 31 August 1998; "world crisis" – from 1 September 1998 to 31 December 1998; and "post-crisis" – the first eight months of 1999.[6] The Asian crisis period spans 16 calendar months, starting at the beginning of the month in which the first major news event occurred (see the Appendix). We defined the end of the Asian crisis as being the onset of financial crises outside the Asian region; accordingly, we separately identify a "world crisis" period, which we take as ending at the end of 1998 when most markets had calmed down considerably. The post-crisis period is therefore limited to the first eight months of 1999.

We were constrained from beginning the pre-crisis period any earlier than January 1994 by the availability of the composite Asian financial indices described and used in Section 4. We also wanted to avoid selecting a sample for the pre-crisis period that was too short, as the exact beginning of the Asian crisis is not necessarily clear. As early as July 1996, there was notable pressure on the Thai baht, following the collapse of the Bangkok Bank of Commerce. There was also pressure in January 1997, following the release of poor export and fiscal data (IMF (1998)). Therefore, we chose to start the sample long before there was any indication of trouble in the region.

Another advantage of the 1994 starting date is that it captures the onset of the global bond bear market in February 1994. This period was characterised by falling bond prices and more volatile financial markets in general. It was followed by a substantial recovery in financial markets, which continued through to the beginning of the Asian crisis period. Capturing both market phases seemed a balanced approach, rather than constructing a sample period characterised by a bull or bear market alone. Moreover, differences between the pre-crisis and Asian crisis periods might then be reasonably attributed to the Asian crisis, rather than simply being due to the comparison between a turbulent period and a relatively calm period in financial markets.

2.4.1 Stock market volatility

Figure 1 plots the absolute daily percentage change in Australian and New Zealand stocks during the four periods described above. The standard pattern of financial market volatility is apparent: in both countries, stock market volatility fluctuates over time and tends to "cluster", i.e. particularly turbulent days tend to be followed by turbulent days and relatively calm days tend to be bunched together. Volatility of Australian stocks appears, on average, to be slightly lower than for New Zealand,

---

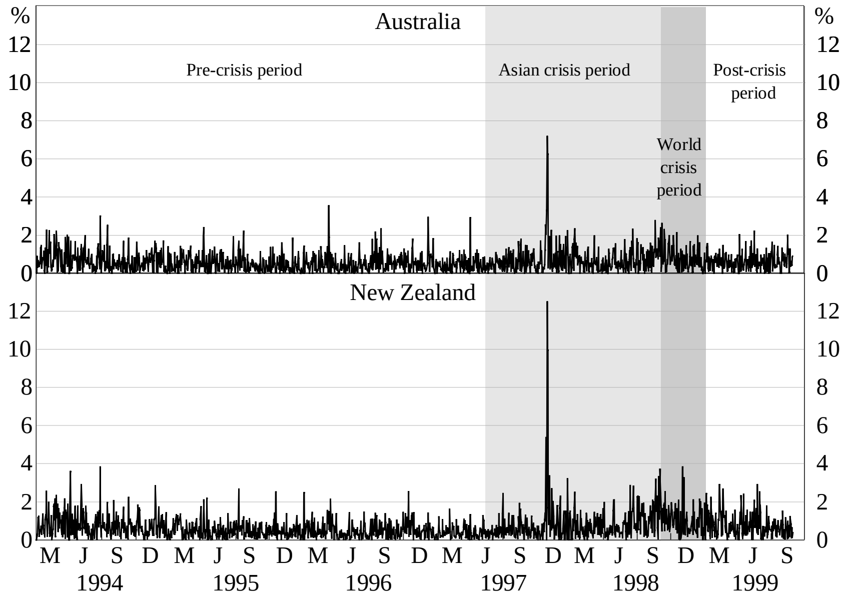
5 We calculated a measure of daily realised volatility (the logarithm of the summation of log-intraday returns – see Andersen et al. (1999) for a derivation) using 10-minute observations of Australian stocks, Australian dollar/US dollar bilateral exchange rates and New Zealand dollar/US dollar bilateral exchange rates. We then estimated the density of these series using a standard kernel density estimation procedure, with an Epanechnikov kernel and Silverman (1986) bandwidth selection. We found a considerable degree of excess kurtosis relative to the corresponding normal (Gaussian) distribution. These results are available from the authors.

6 This rather arbitrary dating is not the only way to define periods of crisis. Eichengreen et al. (1995, 1996) define a crisis period by the occurrence of extreme values of an index of "exchange market pressure", defined as a weighted average of movements in exchange rates, interest rates and international reserves, relative to interest rate and reserves changes in a numeraire country.

although overall the patterns of fluctuations look very similar. This is evident throughout most of the sample, but most clearly during late October 1997 – where the large spikes represent the large stock market sell-off at that time – and subsequently in the world crisis period.[7] There does not appear to be much difference in volatility between the pre-crisis, Asian crisis and post-crisis periods (with the exception of the large spike in October 1997), whereas the world crisis period clearly exhibits a higher level of volatility for both countries.

Figure 1

Stock market volatility



2.4.2 Bond market volatility

It is clear that volatility in bond market returns – the absolute percentage change in the price on the futures contract – is much smaller than stock price volatility (Figure 2). However, there appears to be more evidence of volatility clustering in the bond market, with the 1994 period characterised by very volatile returns, followed by a period of relative calm in the second half of 1995. Again, these patterns are evident in both Australia and New Zealand, although, unlike the case for stock price volatility, bond price volatility is much higher for Australia and appears to be more persistent. Overall, however, volatility in the Australian and New Zealand bond markets seems highly correlated, with volatility in the pre-crisis period much higher for both countries than in the other periods. This is consistent with the global sell-off in bond markets throughout 1994 and early 1995, on fears of rising inflation, compounded by monetary policy tightenings in Australia and New Zealand at that time.

2.4.3 Foreign exchange market volatility

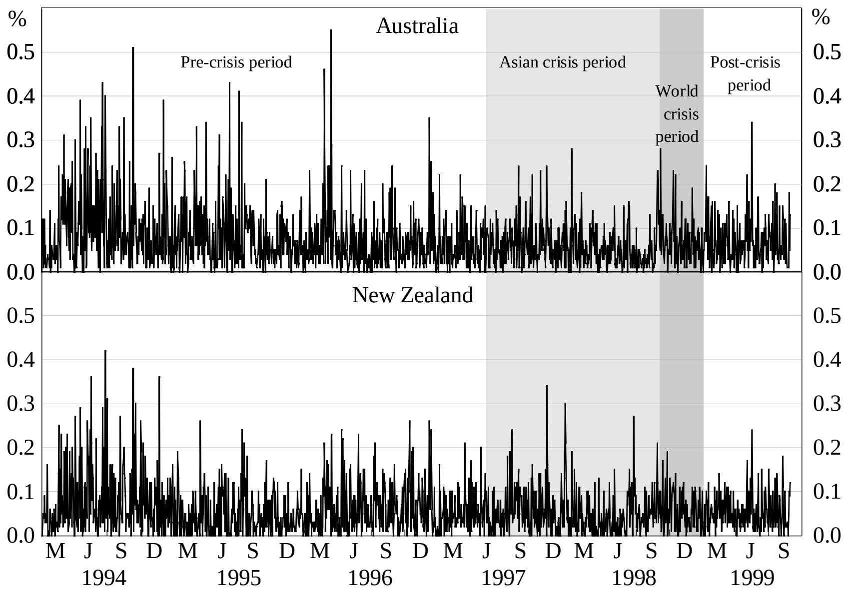
Volatility of both the Australian dollar and the New Zealand dollar exchange rates against the US dollar increased markedly during the Asian crisis, building towards the end of the period, and remained high into the world crisis period (Figure 3). This result suggests that the Asian and world crises had their largest impacts on the exchange rates of the two countries. The increased daily volatility during the later part of the Asian crisis period and in the world crisis period was associated with large depreciations in both bilateral exchange rates. By contrast, the bond and stock markets rallied during most of this period. In part, this may reflect a "flight to quality" by investors.

---

[7] Over the whole period, the average absolute daily percentage change in Australian stocks was 0.6%, compared to 0.7% for New Zealand. However, in the period since October 1997, average volatility has increased to 0.7% and 0.9%.

Figure 2

Bond market volatility



Although the volatility in the exchange rates of the two currencies against the US dollar varied considerably in the crisis periods, the volatility in the Australian dollar/new Zealand dollar cross rate was relatively stable (Figure 4), despite the differences in the operational regimes and stances of monetary policy between the two countries. During the Asian and world crises, the monetary policy instrument was the cash rate in Australia, whereas in New Zealand it was a monetary conditions index (MCI), based on the trade-weighted index for the New Zealand dollar and the three-month bank bill interest rate. The relatively constant volatility of the cross rate reflects that the two currencies are generally traded as a bloc.

Figure 3

Foreign exchange market volatility

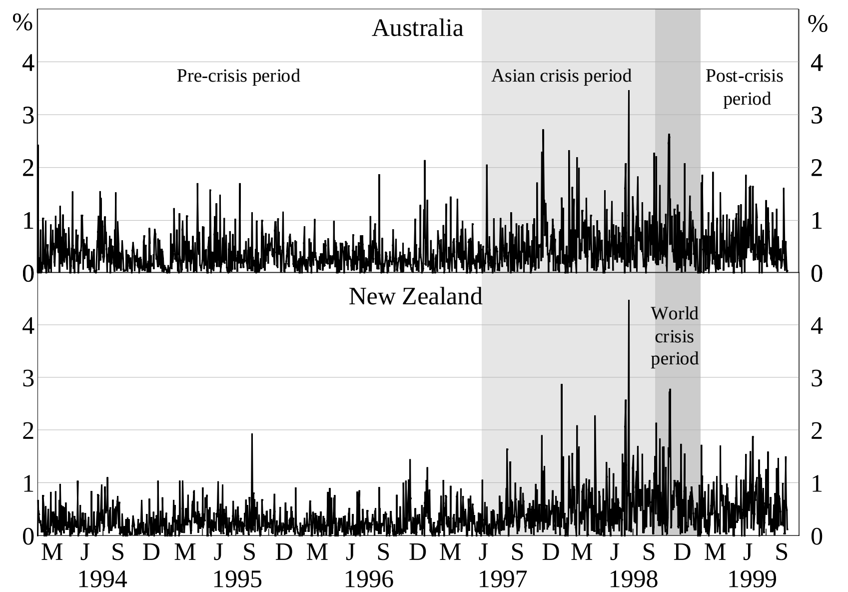
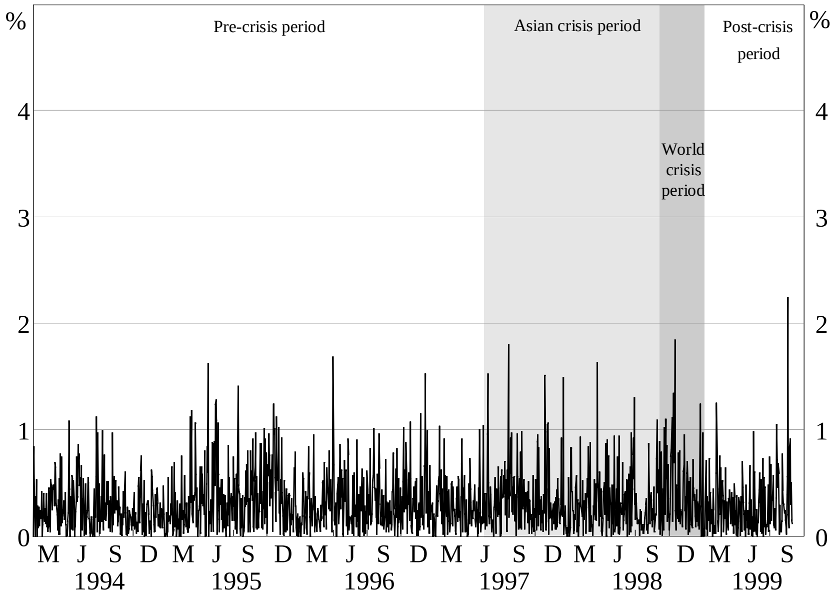


Figure 4

Volatility of the Australian dollar/New Zealand dollar cross rate



3. The response to news

In this section, we use some simple summary statistics and econometric techniques to measure the impact of news on financial market volatility and returns during the Asian crisis.

Within the Asian crisis period, we distinguish between "news" days and "no-news" days, defined as days on which a news event did not occur, and which neither preceded nor followed a news day. Days on which a news event did not occur, but which were adjacent to a news day, are identified separately as "pre-news" and "post-news" days.

3.1 Summary statistics

3.1.1 Stock prices

The first two rows of Table 1 summarise volatility in the Australian and New Zealand stock markets – as measured by the average absolute percentage change in Australian and New Zealand stocks – for all news event days (pre-news, news and post-news days) and no-news days during the Asian crisis period. The table also shows the corresponding measures for the world crisis, pre-crisis and post-crisis periods, as well as the Asian crisis period taken as a whole. Table 2 and Table 3 present mean difference tests of the significance of the differences between these measures.

Several facts stand out. Firstly, during the Asian crisis, all news event days were noticeably more volatile for both Australian and New Zealand stock indices than were days when news events did not occur. Secondly, volatility in both stock indices in the pre-crisis period was significantly lower (in a statistical sense) than during the Asian crisis, but similar to no-news days during the crisis. It was also lower than in both subsequent periods (world crisis and post-crisis). Thirdly, volatility in the world crisis period was similar to the Asian crisis for Australian stocks, but for New Zealand stocks the world crisis period exhibited significantly higher volatility.

3.1.2 Bond futures prices

The variation in bond market volatility was much smaller than for the other financial markets considered. For both Australia and New Zealand, there was seldom more than 0.01 percentage points difference between the mean absolute movements in the bond futures prices across the sub-periods (Table 1). The mean difference tests shown in Table 2 and Table 3 do not indicate any significant news effects during the Asian crisis period for Australia or New Zealand. Pre-news days, news days and post-news days did not engender any greater volatility in Australian and New Zealand bond markets, on average, than days when news events did not occur. Reflecting the severe sell-off in bond markets in 1994, mean volatility in the pre-crisis period was significantly greater than for the Asian and post-crisis periods for both the Australian and New Zealand markets, but not greater than in the world crisis period. Although these are statistically significant differences, they are very small from an economic perspective.

Table 1

Daily financial market volatility:
average absolute daily percentage returns

	News days during Asian crisis				Pre-crisis	Asian crisis	World crisis	Post-crisis
	Pre-news	News	Post-news	No news				
Stock prices								
Australia	0.77	0.91	1.00	0.59	0.55	0.70	0.77	0.62
New Zealand	1.01	0.97	1.24	0.63	0.55	0.79	1.03	0.74
Bond prices								
Australia	0.06	0.06	0.06	0.06	0.08	0.06	0.07	0.07
New Zealand	0.05	0.05	0.07	0.05	0.06	0.05	0.06	0.05
Exchange rates								
Australia	0.59	0.67	0.66	0.46	0.33	0.52	0.62	0.52
New Zealand	0.56	0.63	0.62	0.44	0.26	0.51	0.65	0.52

Note: There are 868 pre-crisis days, 348 Asian crisis days, 88 world crisis days and 173 post-crisis days. During the crisis period, there are 65 news days, 196 no-news days, 65 pre-news and 64 post-news days. There are 42 days that fall into more than one category.

3.1.3 Exchange rates

The effect of the Asian crisis on Australian and New Zealand financial markets is particularly evident for exchange rates. There was an apparent news effect: the mean absolute returns on all news event days were significantly greater than for no-news days for both exchange rates. In the Asian crisis, world crisis and post-crisis periods, both exchange rates were significantly more volatile, on average, than in the pre-crisis period. This suggests that these differences reflected a generalised increase in volatility stemming from heightened uncertainty triggered by the crises. Moreover, the world crisis period exhibited greater volatility than the Asian crisis period in both countries, although not significantly so for Australia.

3.1.4 Comparing Australia and New Zealand

In Section 2.1 above, we discussed a number of reasons why financial markets in Australia and New Zealand might react to news events in Asia. The degree of the responses, however, may not be the same. For example, there may be differing degrees of macroeconomic integration with the crisis countries. There could be different expectations about the likelihood of the crisis spreading to these economies. The reactions could also reflect differences in markets' expectations of the potential responses by the monetary authorities in each country, or market reactions to different monetary policy actions that actually occurred. (Australia and New Zealand were conducting monetary policy using different operational regimes at the time of the crisis.) Finally, there is a possibility that financial markets in different countries react differently to policy actions that appear identical.

Table 2
Mean difference test statistics, Australia: differences between average absolute daily returns by type of day

	News days during Asian crisis				Pre-crisis	Asian crisis	World crisis	Post-crisis
	Pre-news	News	Post-news	No news				
Stock prices								
Pre-news	–	–0.96	–1.38	**1.88**	**2.46**	0.69	–0.04	1.58
News	0.96	–	–0.46	**2.43**	**2.81**	1.59	0.99	**2.22**
Post-news	1.38	0.46	–	**2.68**	**3.00**	**1.96**	1.43	**2.50**
No news	–1.88	–2.43	–2.68	–	1.01	–2.07	–2.35	–0.58
Pre-crisis	–2.46	–2.81	–3.00	–1.01	–	–3.51	–3.16	–1.79
Asian crisis	–0.69	–1.59	–1.96	**2.07**	**3.51**	–	–0.89	1.56
World crisis	0.04	–0.99	–1.43	**2.35**	**3.16**	0.89	–	**1.99**
Post-crisis	–1.58	–2.22	–2.50	0.58	**1.79**	–1.56	–1.99	–
Bond prices								
Pre-news	–	0.11	–0.32	0.68	–2.33	0.40	–0.86	–0.72
News	–0.11	–	–0.43	0.55	–2.53	0.26	–0.99	–0.87
Post-news	0.32	0.43	–	1.09	–1.90	0.82	–0.50	–0.33
No news	–0.68	–0.55	–1.09	–	–5.44	–0.54	–2.00	–2.11
Pre-crisis	**2.33**	**2.53**	**1.90**	**5.44**	–	**5.52**	1.58	**2.37**
Asian crisis	–0.40	–0.26	–0.82	0.54	–5.52	–	–1.72	–1.81
World crisis	0.86	0.99	0.50	**2.00**	–1.58	**1.72**	–	0.26
Post-crisis	0.72	0.87	0.33	**2.11**	–2.37	**1.81**	–0.26	–
Exchange rates								
Pre-news	–	–0.84	–0.78	**1.80**	**3.85**	0.93	–0.39	0.92
News	0.84	–	0.09	**2.69**	**4.61**	**1.92**	0.48	**1.87**
Post-news	0.78	–0.09	–	**2.79**	**4.93**	**1.96**	0.41	**1.90**
No news	–1.80	–2.69	–2.79	–	**3.74**	–1.59	–2.38	–1.37
Pre-crisis	–3.85	–4.61	–4.93	–3.74	–	–6.75	–4.60	–5.34
Asian crisis	–0.93	–1.92	–1.96	1.59	**6.75**	–	–1.50	0.05
World crisis	0.39	–0.48	–0.41	**2.38**	**4.60**	1.50	–	1.46
Post-crisis	–0.92	–1.87	–1.90	1.37	**5.34**	–0.05	–1.46	–

Note: Boldface indicates that the type of day listed in the row label was significantly more volatile, on average, than the type of day listed in the column.

In Table 4, we compare the average volatility of financial markets in Australia and New Zealand, using the same mean difference test statistic as in the previous subsections.[8] For the stock market, the results are unambiguous: in the crisis periods and the post-crisis period, the mean volatility is larger in New Zealand. However, this difference between countries is significant only during the world crisis and post-crisis periods. There could be a number of reasons for this, not least that the New Zealand stock price index, being relatively small, was more susceptible to being moved by large liquidity flows during the second half of 1998. In any case, this difference is unrelated to the Asian crisis period and therefore cannot be attributed to differences in the authorities' responses to the Asian crisis, or to different market expectations about the implications of the crisis. A similar pattern can be seen in the results for bonds and exchange rates: where differences between Australia and New Zealand exist, they occur in the pre-crisis or post-crisis periods. The crisis periods seem to have resulted in greater

8 Using a two-tailed test, not a one-tailed test as in the previous section.

similarity between markets. A possible explanation for this is that both markets were driven by overseas events during the crises, and to about the same extent, while at other times they were driven by country-specific shocks.

Table 3
Mean difference test statistics, New Zealand: differences between average absolute daily returns by type of day

	News days during Asian crisis				Pre-crisis	Asian crisis	World crisis	Post-crisis
	Pre-news	News	Post-news	No news				
Stock prices								
Pre-news	–	0.19	–0.83	**2.98**	**3.69**	1.61	–0.10	**2.09**
News	–0.19	–	–0.86	**1.68**	**2.07**	0.84	–0.27	1.13
Post-news	0.83	0.86	–	**2.41**	**2.72**	**1.74**	0.81	**1.97**
No news	–2.98	–1.68	–2.41	–	**1.73**	–2.43	–4.32	–1.77
Pre-crisis	–3.69	–2.07	–2.72	–1.73	–	–4.06	–5.52	–3.59
Asian crisis	–1.61	–0.84	–1.74	**2.43**	**4.06**	–	–2.30	0.78
World crisis	0.10	0.27	–0.81	**4.32**	**5.52**	**2.30**	–	**3.01**
Post-crisis	–2.09	–1.13	–1.97	**1.77**	**3.59**	–0.78	–3.01	–
Bond prices								
Pre-news	–	0.11	–1.44	–0.10	–1.78	–0.21	–0.73	–0.40
News	–0.11	–	–1.41	–0.21	–1.57	–0.31	–0.74	–0.46
Post-news	1.44	1.41	–	1.50	0.43	1.49	0.95	1.33
No news	0.10	0.21	–1.50	–	–2.27	–0.13	–0.76	–0.37
Pre-crisis	**1.78**	1.57	–0.43	**2.27**	–	**2.56**	1.03	**2.05**
Asian crisis	0.21	0.31	–1.49	0.13	–2.56	–	–0.72	–0.28
World crisis	0.73	0.74	–0.95	0.76	–1.03	0.72	–	0.47
Post-crisis	0.40	0.46	–1.33	0.37	–2.05	0.28	–0.47	–
Exchange rates								
Pre-news	–	–0.74	–0.78	**1.80**	**5.41**	0.87	–1.04	0.66
News	0.74	–	0.05	**2.31**	**5.09**	1.57	–0.20	1.39
Post-news	0.78	–0.05	–	**2.64**	**6.13**	**1.80**	–0.28	1.57
No news	–1.80	–2.31	–2.64	–	**5.51**	–1.49	–2.89	–1.65
Pre-crisis	–5.41	–5.09	–6.13	–5.51	–	–9.09	–6.25	–8.27
Asian crisis	–0.87	–1.57	–1.80	1.49	**9.09**	–	–2.09	–0.29
World crisis	1.04	0.20	0.28	**2.89**	**6.25**	**2.09**	–	**1.86**
Post-crisis	–0.66	–1.39	–1.57	**1.65**	**8.27**	0.29	–1.86	–

Note: Boldface indicates that the type of day listed in the row label was significantly more volatile, on average, than the type of day listed in the column.

Table 4
Mean difference tests between Australia and New Zealand

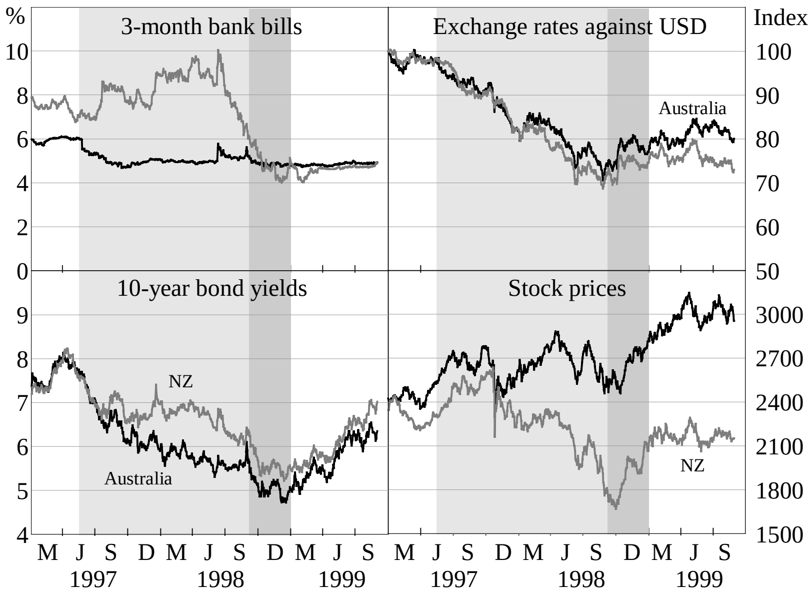
	News days during Asian crisis				Pre-crisis	Asian crisis	World crisis	Post-crisis
	Pre-news	News	Post-news	No news				
Stock prices								
Australia								
– Mean volatility	0.77	0.91	1.00	0.59	0.55	0.70	0.77	0.62
– Sample variance	0.47	1.05	1.42	0.25	0.24	0.52	0.39	0.20
New Zealand								
– Mean volatility	1.01	0.97	1.24	0.63	0.55	0.79	1.03	0.74
– Sample variance	0.97	2.57	4.05	0.29	0.26	1.11	0.61	0.39
Test statistic	–1.64	–0.23	–0.82	–0.67	–0.07	–1.35	–2.39	–1.97
Decision	Same	Same	Same	Same	Same	Same	Aust<NZ	Aust<NZ
Bond prices								
Australia								
– Mean volatility	0.06	0.06	0.06	0.06	0.08	0.06	0.07	0.07
– Sample variance	0.003	0.003	0.003	0.002	0.006	0.002	0.003	0.003
New Zealand								
– Mean volatility	0.05	0.05	0.07	0.05	0.06	0.05	0.06	0.05
– Sample variance	0.002	0.003	0.004	0.003	0.004	0.003	0.002	0.002
Test statistic	1.12	1.01	–0.07	0.80	5.11	1.46	1.73	2.56
Decision	Same	Same	Same	Same	Aust>NZ	Same	Same	Aust>NZ
Exchange rates								
Australia								
– Mean volatility	0.59	0.67	0.66	0.46	0.33	0.52	0.62	0.52
– Sample variance	0.27	0.33	0.27	0.19	0.10	0.23	0.33	0.19
New Zealand								
– Mean volatility	0.56	0.63	0.62	0.44	0.26	0.51	0.65	0.52
– Sample variance	0.20	0.34	0.23	0.22	0.06	0.24	0.34	0.16
Test statistic	0.31	0.39	0.39	0.30	5.87	0.41	–0.29	0.04
Decision	Same	Same	Same	Same	Aust>NZ	Same	Same	Same

Note: The null hypothesis is that the mean volatility in the two markets is the same on that category of day. The two-sided alternative is that they are different.

While the volatility in the two countries' financial markets was very similar during the Asian crisis, the *levels* of the financial-market variables suggest that conditions in Australian and New Zealand stock and bond markets were rather different during this period (Figure 5).

Figure 5

Australian and New Zealand financial markets



3.2 Econometric evidence

In this section, we seek to further quantify the effect of news on financial markets using econometric methods. Based on our chronology, we constructed a news event "dummy" series which took the value +1 for good news, –1 for bad news, and zero otherwise. We then estimated vector autoregressions (VARs) of the daily returns on Australian and New Zealand assets and on a benchmark US financial asset (the S&P 500 stock price index and the futures contract on the 30-year benchmark Treasury bond) for the pre-crisis, world crisis and post-crisis periods. For the Asian crisis period, we augmented the VAR with the current and lagged values of the news event dummy series. This is similar to the methodology used by Baig and Goldfajn (1999).

Since bilateral exchange rates are relative prices – in this case to the US dollar – it is not possible to use this exact approach for the exchange rates. Instead, we estimated VARs of the Australian dollar and New Zealand dollar rates against the US dollar with the CRB Commodity Price Index, which is intended to proxy for the effects of global shocks on commodity-exporting countries.[9] For each of the VAR systems, we used two lags of the endogenous variables, which was the preferred number of lags according to the Schwartz Information Criterion. We included the current-dated and first lag of the news variable for the Asian crisis period.

The results from these models should be taken as indicative rather than decisive, not least because linear VARs are hardly the best available model of financial asset returns. In particular, the residuals from most of these models are non-normal; specifically, they have marked ARCH properties. However, when we estimated single-equation models incorporating the same variables and lag structure as these VARs, allowing for GARCH residuals, the qualitative results on the importance of the news events in Asia and US developments were unchanged. It is also not feasible to estimate multivariate GARCH models using our data set. Because non-trading days are not identical across markets, there are missing values, which can distort estimation of the process for the error variance.

9 Westpac Banking Corporation produces a real-time commodity price index that better reflects the composition of Australia's exports. Although back-data is available, this index was not available to traders until 1999. In any case, estimation of the exchange rate VAR using the WBC index instead of the CRB index gives similar results.

Table 5
VAR estimates for daily stock returns

	Pre-crisis			Asian crisis			World crisis			Post-crisis		
	AOI	**NZSE40**	**S&P**	**AOI**	**NZSE40**	**S&P**	**AOI**	**NZSE40**	**S&P**	**AOI**	**NZSE40**	**S&P**
Constant	–0.02	–0.03	0.06**	–0.02	–0.08	0.05	0.04	0.04	0.38**	–0.03	–0.01	–0.03
	(–0.72)	(–1.31)	(2.21)	(–0.48)	(–1.52)	(0.67)	(0.45)	(0.28)	(2.15)	(-0.63)	(–0.23)	(–0.25)
AOI_{-1}	0.07	0.17***	0.01	0.00	0.33***	–0.08	–0.17	0.07	–0.21	–0.12	0.13	0.03
	(1.59)	(3.76)	(0.30)	(0.08)	(4.29)	(–0.83)	(–1.45)	(0.45)	(–0.97)	(–1.35)	(1.18)	(0.20)
AOI_{-2}	–0.06	0.00	–0.03	0.07	0.14*	0.02	–0.05	–0.02	–0.16	–0.05	0.20***	0.04
	(–1.64)	(0.06)	(–0.74)	(1.21)	(1.80)	(0.24)	(–0.49)	(–0.13)	(–0.85)	(–0.69)	(1.97)	(0.30)
$NZSE40_{-1}$	–0.04	0.02	0.04	–0.06	–0.08	0.05	–0.04	–0.04	0.12	–0.03	0.12	–0.20
	(–0.95)	(0.45)	(1.07)	(–1.16)	(–1.26)	(0.62)	(–0.48)	(–0.35)	(0.74)	(–0.46)	(1.41)	(–1.61)
$NZSE40_{-2}$	0.03	0.04	0.01	–0.01	–0.02	0.08	–0.08	0.14	–0.02	0.07	–0.16**	0.03
	(0.83)	(0.88)	(0.32)	(–0.20)	(–0.27)	(1.11)	(–1.01)	(1.36)	(–0.16)	(1.19)	(–1.97)	(0.28)
$S\&P_{-1}$	0.57***	0.43***	0.09**	0.45***	0.45***	0.09	0.38***	0.46***	–0.09	0.38***	0.35***	–0.02
	(15.27)	(10.66)	(2.27)	(10.63)	(8.54)	(1.45)	(6.61)	(5.88)	(–0.83)	(8.27)	(5.77)	(–0.23)
$S\&P_{-2}$	–0.14***	–0.11**	–0.01	0.08	–0.04	–0.04	0.05	0.03	–0.08	0.02	–0.17**	0.15
	(–3.15)	(–2.38)	(–0.33)	(1.57)	(–0.72)	(–0.55)	(0.72)	(0.29)	(–0.59)	(0.42)	(–2.24)	(1.40)
"News"	–	–	–	0.14	0.21	0.03*	–	–	–	–	–	–
				(1.29)	(1.60)	(1.87)						
"News"_{-1}	–	–	–	0.01	–0.06	–0.13	–	–	–	–	–	–
				(0.14)	(–0.42)	(–0.81)						
R-bar squared	0.26	0.17	0.00	0.28	0.27	0.01	0.36	0.33	–0.02	0.31	0.22	–0.01
S.E. regression	0.65	0.70	0.66	0.73	0.90	1.10	0.80	1.10	1.48	0.64	0.83	1.18
F-statistic	42.15	24.54	1.29	15.13	14.18	1.24	7.81	7.19	0.74	11.92	7.69	0.65
Jarque-Bera stat.	22.77	32.14	98.75	0.51	48.32	238.24	0.50	9.04	1.10	1.73	1.73	2.39

Notes: ***, ** and * indicate significant at the 1, 5 and 10% levels. t-statistics are in parentheses. The residuals do not display significant serial correlation.

Table 6
VAR estimates for daily bond returns

	Pre-crisis			**Asian crisis**			**World crisis**			**Post-crisis**		
	Australia	**NZ**	**US**	**Australia**	**NZ**	**US**	**Australia**	**NZ**	**US**	**Australia**	**NZ**	**US**
Constant	0.00	0.00	0.00	0.02	0.00	0.04	0.01	0.01*	–0.07	–0.01	–0.01**	–0.09*
	(0.55)	(–0.43)	(–0.18)	(0.52)	(0.91)	(1.34)	(1.47)	(1.75)	(–0.86)	(–1.15)	(–2.02)	(–1.94)
Australia$_{-1}$	–0.14***	0.06	0.24	–0.02	0.04	–0.12	–0.41***	–0.02	–1.18	–0.25**	–0.02	–0.08
	(–3.31)	(1.40)	(0.80)	(–0.32)	(0.58)	(–0.25)	(–2.74)	(–0.19)	(–0.85)	(–2.50)	(–0.24)	(–0.07)
Australia$_{-2}$	0.00	0.21	0.03	–0.10	0.01	–0.51	–0.13	–0.05	–0.82	0.19**	0.19***	0.62
	(–0.02)	(0.58)	(0.12)	(–1.61)	(0.18)	(–1.18)	(–0.96)	(–0.45)	(–0.65)	(2.02)	(2.63)	(0.61)
NZ$_{-1}$	–0.11**	–0.19***	0.45	0.05	–0.10	0.15	0.14	–0.13	0.34	–0.16	–0.18*	0.13
	(–2.31)	(–4.20)	(1.34)	(0.79)	(–1.52)	(0.34)	(0.79)	(–0.84)	(0.21)	(–1.19)	(–1.75)	(0.08)
NZ$_{-2}$	–0.04	–0.04	0.12	0.01	–0.03	0.01	0.04	0.00	0.32	–0.44***	–0.31***	–1.69
	(–0.76)	(–0.79)	(0.37)	(0.16)	(–0.54)	(0.02)	(0.28)	(0.01)	(0.21)	(–3.72)	(–3.32)	(–1.29)
US$_{-1}$	0.12***	0.08***	–0.04	0.09***	0.07**	0.06	0.06***	0.06***	0.28**	0.14***	0.11***	–0.02
	(19.21)	(14.03)	(–0.87)	(10.67)	(6.96)	(0.99)	(4.53)	(5.42)	(2.27)	(16.96)	(17.17)	(–0.32)
US$_{-2}$	0.01*	0.00	–0.08	–0.01	–0.02	–0.01	0.03	0.03**	0.23	0.04***	0.02*	0.02
	(1.68)	(0.48)	(–1.40)	(–1.02)	(–1.57)	(–0.09)	(1.51)	(2.19)	(1.38)	(2.98)	(1.73)	(0.15)
"News"	–	–	–	–0.01	0.01	0.00	–	–	–	–	–	–
				(–1.27)	(0.53)	(0.01)						
"News"$_{-1}$	–	–	–	0.01	0.01	–0.04	–	–	–	–	–	–
				(0.57)	(0.71)	(–0.66)						
R-bar squared	0.39	0.26	0.00	0.29	0.14	–0.02	0.24	0.30	0.03	0.67	0.67	–0.02
SE regression	0.09	0.08	0.60	0.06	0.07	0.45	0.07	0.06	0.65	0.05	0.04	0.56
F-statistic	64.20	36.14	0.72	15.38	6.86	0.44	4.57	5.95	1.30	49.92	50.96	0.47
Jarque-Bera stat.	189.44	32.58	29.98	37.42	103.58	30.18	8.31	1.30	0.64	1.03	1.42	6.02

Notes: ***, ** and * indicate significant at the 1, 5 and 10% levels. t-statistics are in parentheses. The residuals do not display significant serial correlation.

Table 7

VAR estimates for daily exchange rate returns

	Pre-crisis			Asian crisis			World crisis			Post-crisis		
	A$	**NZ$**	**CRB**	**A$**	**NZ$**	**CRB**	**A$**	**NZ$**	**CRB**	**A$**	**NZ$**	**CRB**
Constant	0.02	0.03**	0.02	–0.05	–0.08*	–0.05	0.10	0.04	–0.06	0.02	–0.01	0.04
	(0.99)	(2.47)	(1.00)	(–1.17)	(–1.89)	(–1.52)	(1.26)	(0.45)	(–0.78)	(0.39)	(–0.19)	(0.74)
A$$_{-1}$$	–0.03	0.04	–0.07	0.00	0.07	0.12	0.30*	0.29	0.09	–0.05	–0.08	–0.08
	(–0.70)	(1.31)	(–1.50)	(0.02)	(0.74)	(1.60)	(1.81)	(1.53)	(0.61)	(–0.33)	(–0.61)	(–0.57)
A$$_{-2}$$	0.00	0.00	0.01	–0.04	–0.05	0.12*	–0.12	0.16	–0.12	0.01	–0.09	–0.14
	(0.06)	(0.10)	(0.22)	(–0.43)	(–0.58)	(1.66)	(–0.72)	(0.86)	(–0.82)	(0.15)	(–0.73)	(–1.09)
NZ$$_{-1}$$	0.03	0.00	0.02	0.00	–0.08	0.00	–0.12	–0.10	–0.02	–0.06	0.01	0.12
	(0.57)	(–0.04)	(0.37)	(–0.04)	(–0.80)	(–0.05)	(–0.85)	(–0.62)	(–0.19)	(–0.45)	(0.04)	(0.85)
NZ$$_{-2}$$	–0.04	–0.11**	–0.05	–0.10	–0.13	–0.06	0.13	0.05	0.18	0.04	0.04	0.05
	(–0.69)	(–2.49)	(–0.83)	(–1.19)	(–1.43)	(–0.92)	(0.94)	(0.29)	(1.36)	(0.31)	(0.34)	(0.41)
CRB$_{-1}$	0.06*	0.02	0.05	0.25***	0.27***	0.01	0.56***	0.46***	–0.07	0.42***	0.43***	0.08
	(1.65)	(0.64)	(1.39)	(3.40)	(3.52)	(0.23)	(4.66)	(3.25)	(–0.63)	(4.74)	(5.13)	(0.89)
CRB$_{-2}$	0.04	0.02	0.00	–0.06	–0.07	–0.07	–0.08	–0.09	0.08	0.05	0.07	–0.04
	(1.08)	(0.57)	(–0.01)	(–0.86)	(–1.03)	(–1.27)	(–0.62)	(–0.58)	(0.66)	(0.56)	(0.83)	(–0.45)
"News"	–	–	–	0.06	0.02	0.00	–	–	–	–	–	–
				(0.65)	(0.19)	(0.04)						
"News"$_{-1}$	–	–	–	0.17*	0.17*	–0.07	–	–	–	–	–	–
				(1.85)	(1.77)	(–0.87)						
R-bar squared	0.00	0.01	0.00	0.04	0.05	0.01	0.21	0.14	–0.02	0.12	0.14	–0.02
SE regression	0.47	0.36	0.49	0.67	0.68	0.53	0.69	0.80	0.65	0.64	0.62	0.63
F-statistic	0.84	1.82	0.81	2.58	3.08	1.47	4.50	3.15	0.69	4.30	4.85	0.59
Jarque-Bera stat.	86.90	108.37	35.62	37.39	278.11	8.95	0.33	0.30	4.50	1.41	0.43	3.78

Notes: ***, ** and * indicate significant at the 1, 5 and 10% levels. t-statistics are in parentheses. The residuals do not display significant serial correlation.

The VAR results for the stock market are shown in Table 5. The estimated coefficients on the news dummy series are positive but insignificant for Australian and New Zealand stocks. The coefficients on the lagged S&P 500, however, are large and highly significant for both countries in all periods. This suggests that the news dummies do not appear to have much independent effect on Australian and New Zealand stock markets, once overnight events in US markets are controlled for; these markets are dominated by overnight developments in the United States.[10] However, there is some evidence that Australian and New Zealand market participants react to events in Asia *indirectly* via the United States. The contemporaneous news dummies are just significant in the equation for the S&P 500, and they are of the expected sign. This might explain why the post-news days exhibited greater average volatility in both countries' stock markets than did news days (Table 1). It also suggests possible inefficient information processing. If Asian news had systematically moved the S&P 500, which then systematically moved Australian and New Zealand stock markets, it begs the question why the Australian and New Zealand markets did not react on the day of the news event. One answer may be that timing issues prevented these markets from reacting contemporaneously, for example if the event occurred after the markets closed.

The results for bonds indicate an even smaller response to the news events, once the overnight movements in the US Treasury market are controlled for (Table 6). The estimated coefficients are broadly similar across the four sub-periods, with the inclusion of the news event dummies making little difference to the estimation results for the Asian crisis. Again, overnight movements in the US long bond mattered more for Australian and New Zealand bond returns than did the Asian-crisis news events.

The picture for the exchange rates is somewhat different in that the contemporaneous news dummies are of the right sign but are insignificant, while the lags of the dummies are significant in both the Australian dollar and New Zealand dollar equations (Table 7). The significance of the lagged dummies and not the contemporaneous dummies could possibly be attributed to the timing of the news announcements. The estimated coefficients on the news dummies are positive, implying that bad news in Asia resulted in a depreciation of the Australian and New Zealand dollars against the US dollar.

Interestingly, the CRB index became more significant in later periods. This suggests that market participants looked more closely at commodity price series, such as the CRB index, when assessing the fundamentals underlying these exchange rates.

4. Comparing spillover in crises and at other times

An important question relating to financial stability is whether the spillover of shocks and volatility is greater when the originating markets are in crisis than in more normal times. At first glance, it might be thought that this is true: turbulent markets indicate greater uncertainty about the future, and so uncertainty about the effects of news events on third markets is also likely to be greater during these times.

It is not feasible to answer this question using the news event data described in Section 2.3, however. By construction, there were no news events before or after the Asian crisis period (May 1997–August 1998), so we cannot test whether markets responded more to news events in the Asian crisis period compared with other periods. Instead, we estimate an expanded version of the VARs presented in Section 3.2, with an additional equation in the system to measure movements in Asian financial markets. We present results for returns, rather than volatility (absolute returns), as these were more robust to small specification changes, and allow us to examine the direction as well as the magnitude of the reaction to movements in other markets.

For each market, we present selected impulse responses and variance decompositions, using a recursive-ordering identification scheme with the ordering (Asia, Australia, New Zealand, United

[10] The US market's day *t* occurs after Asian, Australian and New Zealand day *t*, but before their day *t*+1.

States). In general, alternative orderings made little difference to our results on the effect of the Asian variable on returns in Australia and New Zealand, although the relative ordering of Australia and New Zealand can affect the estimates of their effects on each other. The US market generally had no contemporaneous effect on the Australian and New Zealand markets, even when the system was ordered to permit this. We attribute this result to the time zone differences, with the US trading day starting after the close in Asian, Australian and New Zealand markets.

To capture movements in Asian financial markets, we use regional indices. For stock markets, we use the MSCI Far East Free (excluding Japan) index compiled by Morgan Stanley. This index is a market capitalisation-weighted stock price index covering at least 60% of the market capitalisation of each industry group. Only the portion of each country's stock market that is freely available to overseas investors is included. We use these "Free" series on the basis that contagion reflects movements in markets that foreigners can invest in, rather than those which only domestic investors can access. The countries included are listed in column 1 of Table 8, the data are presented in Figure 6.[11] Although we have elected to use a series that incorporates countries other than those most affected by the crisis (i.e. Indonesia, Korea, Thailand, Malaysia and the Philippines), this does not appear to distort our results. We obtained very similar results for the impulse responses and variance decompositions using the MSCI Emerging Markets Far East Index, the MSCI Emerging Markets Asia Index and the first principal component of a data set of stock market returns for the five countries most affected by the Asian crisis.[12]

Analysis of an equivalent VAR system for bond returns is precluded by the lack of long-maturity sovereign debt securities in the crisis-affected countries, equivalent to the benchmark bonds used for Australia, New Zealand and the United States. Instead, we use the JP Morgan EMBI (Emerging Markets Bond Index) Global Constrained Asia sub-index series as a proxy (Figure 7). This series is constructed using US dollar-denominated eurobonds for countries without a well-developed domestic market for sovereign debt.[13] For the exchange rate, we constructed a GDP-weighted fixed-weight exchange rate index based on the spot exchange rates of the four countries listed in the right-most column of Table 8 against the US dollar (Figure 8). The GDP weights were based on 1996 data from the World Bank Atlas, which converts the local currency GDP levels to US dollars using three-year-average exchange rates. A fall in this index represents depreciations of these countries' currencies against the US dollar.

One rationale for using a regional index is that it summarises groups of explanatory variables that are not of interest individually. With multiple individual series (plus lags) in the system, estimated coefficients for the crisis periods compared with non-crisis periods could be higher for some series and lower for others. In that case, it is not clear whether "spillover" in a general sense is greater or smaller during periods of financial crisis. By summarising the data using a regional index (or a principal component), we can get a better sense of the net difference between crisis periods and non-crisis periods.

Furthermore, and not surprisingly, the returns in individual Asian countries are correlated (individual stock market returns have correlation coefficients as high as 0.36). We are less interested in identifying the separate effects of movements in each market than in determining the reaction in Australia and New Zealand to some broadly defined notion of movements in Asian markets. Using the regional index instead of the country-specific data allows us to capture movements in Asian financial markets, while avoiding the problems inherent in estimating systems with multicolinear explanatory variables.

---

[11] Detailed documentation for the MSCI indices is available from Morgan Stanley's website (www.msci.com).

[12] These results are available from the authors. The principal components of a data set are simply a linear transformation of the data into mutually orthogonal components. These components are then ordered so that the first component captures the largest portion of the total information in the data set, the second captures the second largest share, and so on. For an introduction to principal component analysis (PCA), see Cooley and Lohnes (1971) or Chatfield and Collins (1980).

[13] The EMBI Global Constrained Index is a market capitalisation-weighted index, which includes emerging market issues by sovereign and quasi-sovereign entities denominated in US dollars. It only considers issues with a current face value amount outstanding of US$ 500 million or more, with at least two and a half years until maturity. More detailed information on the construction of EMBI Global is available on JP Morgan's website.

Table 8

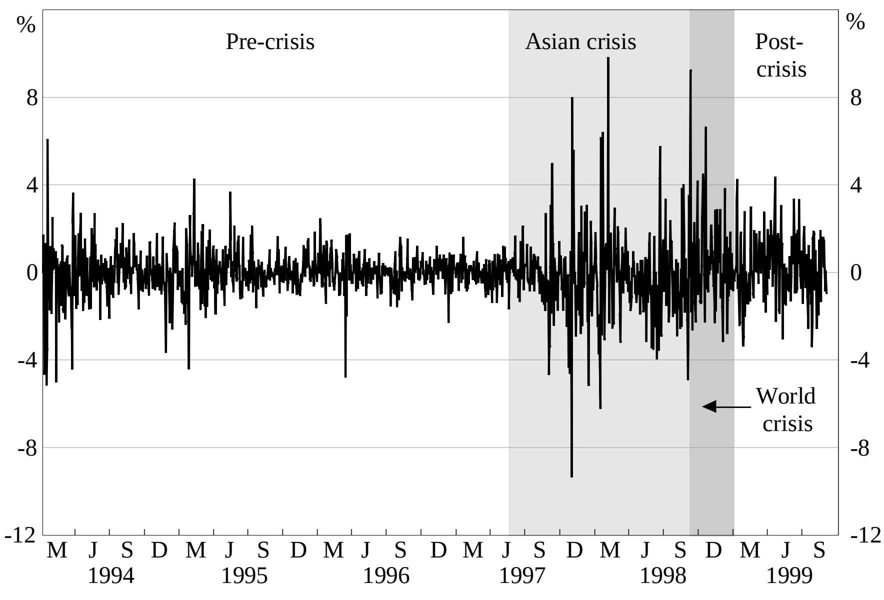
Countries included in alternative Asian region financial indices

MSCI Far East Free (ex. Japan)	MSCI Emerging Markets Far East	MSCI Emerging Markets Asia	EMBI Global Constrained (Asia sub-index)	Troubled Asia Exchange Rate Index
China	China	China	China	
Hong Kong				
		India		
Indonesia	Indonesia	Indonesia		Indonesia (JCI)
Korea	Korea	Korea	Korea	Korea (KOSPI)
Malaysia	Malaysia	Malaysia	Malaysia	Malaysia (KLCI)
		Pakistan		
Philippines	Philippines	Philippines	Philippines	
Singapore				
		Sri Lanka		
Taiwan	Taiwan	Taiwan		
Thailand	Thailand	Thailand	Thailand	Thailand (SET)

Sources: MSCI indices: Morgan Stanley and Bloomberg. EMBI Global: JP Morgan. Exchange rate index compiled by the authors.

Figure 6

Morgan Stanley Far East Asia Free index: daily returns



Another consideration that suggests some sort of data summarisation technique may be more appropriate is the loss of observations due to public holidays and other non-trading days falling on different days in different countries. For the VARs presented in Section 3.2 above, there is enough overlap between non-trading days in the different countries so that the number of observations lost is small. However, when Asian markets are added, around half the total number of observations can be lost due to missing data on non-trading days. This wastage of data points is clearly undesirable. By contrast, the regional indices record price movements for days when some (but not all) of those markets are closed, although possibly at the expense of some measurement error.

Figure 7

EMBI Global Constrained Asia sub-index: daily returns

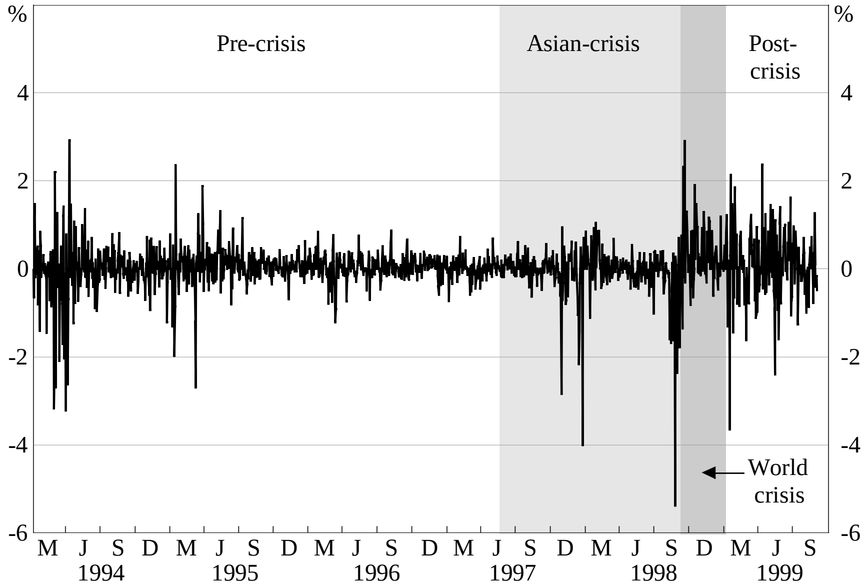
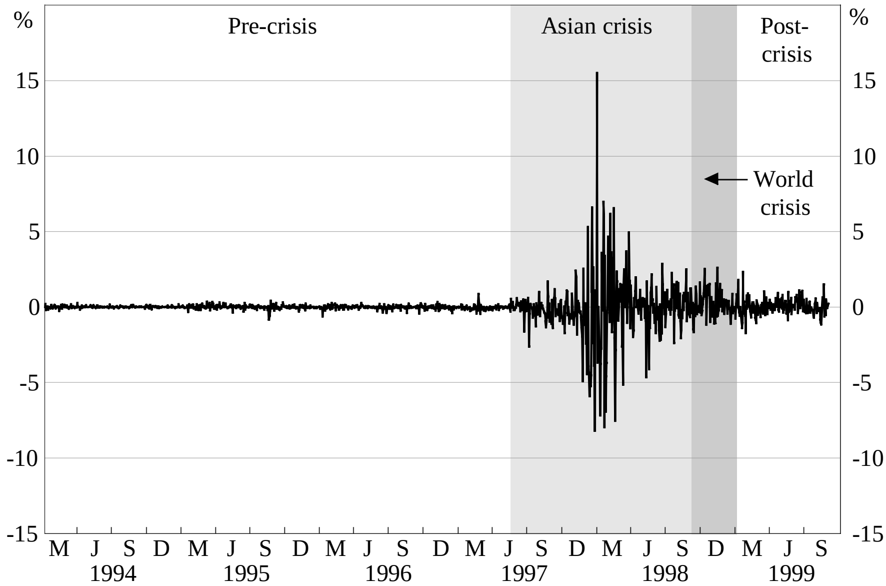


Figure 8

Troubled Asia Exchange Rate Index: daily returns



4.1 Stock markets

Within each sub-period (pre-crisis, Asian crisis, world crisis and post-crisis), our VAR results for stock returns were largely as expected. Much of the variation in Australian and New Zealand returns was driven by overnight developments in US markets. Movements in the Australian and New Zealand markets did not have an independent effect on US markets. There was some minor persistence in Australasian markets, with lagged own price changes being significant in some cases. The previous day’s return in the Australian market also had a significant positive effect on the New Zealand market; we attribute this to time zone differences.[14]

[14] We do not present the estimation results in the paper; they are available from the authors. To save space, we also show only the first, second and fifth days in the variance decompositions.

Figure 9

Impulse responses for pre-crisis stock returns VAR

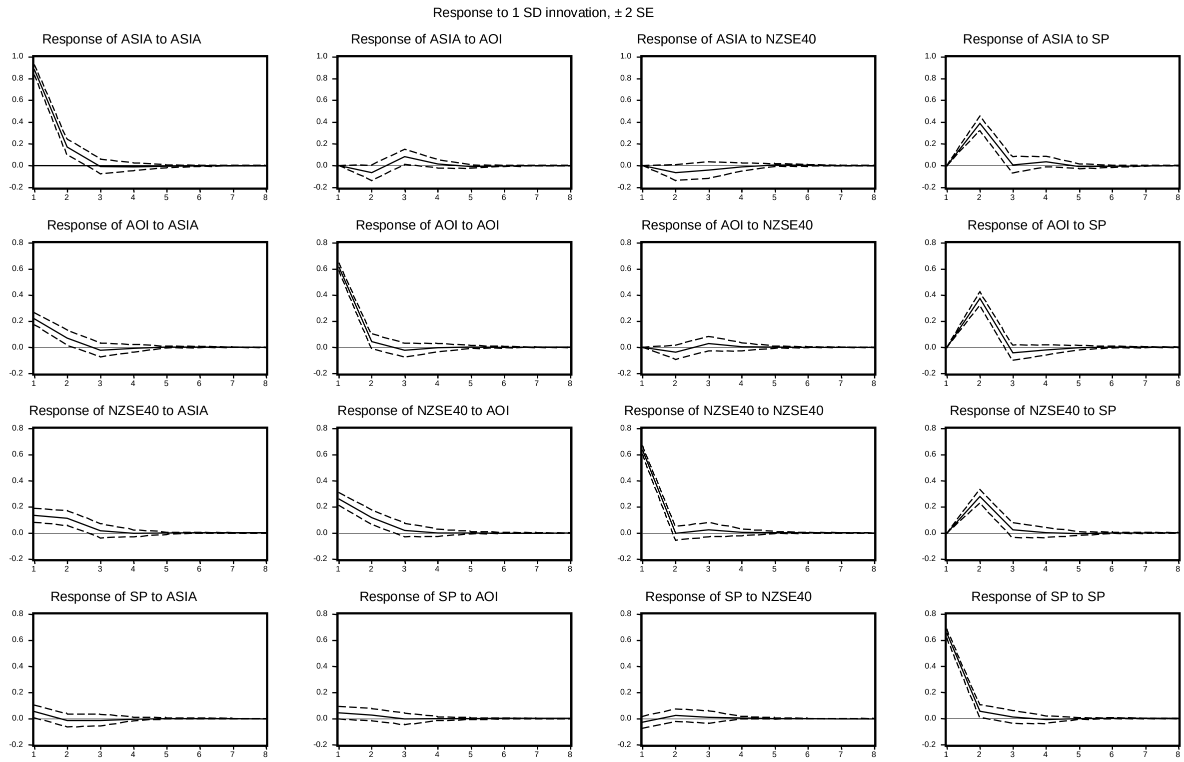


Table 9
Stock returns variance decompositions, pre-crisis

Period	SE	Asia	AOI	NZSE40	SP
Asia: MSCI Far East Free excluding Japan					
1	0.878509	100.0000	0.000000	0.000000	0.000000
2	0.980516	83.29571	0.431031	0.436179	15.83708
5	0.985841	82.42261	1.145628	0.619652	15.81211
All Ordinaries Index					
1	0.652259	11.22335	88.77665	0.000000	0.000000
2	0.757196	9.231658	66.20873	0.265550	24.29406
5	0.759975	9.268215	65.81962	0.401995	24.51017
NZSE40					
1	0.697813	3.729639	13.80512	82.46524	0.000000
2	0.769523	5.196051	13.70929	67.81368	13.28098
5	0.770694	5.219660	13.74559	67.70387	13.33088
S&P 500					
1	0.653492	0.708081	0.475811	0.188500	98.62761
2	0.657131	0.748842	0.656160	0.339144	98.25585
5	0.657529	0.786385	0.657852	0.371244	98.18452

Ordering: Asia AOI NZSE40 SP.

Figure 10
Impulse responses for Asian crisis stock returns VAR

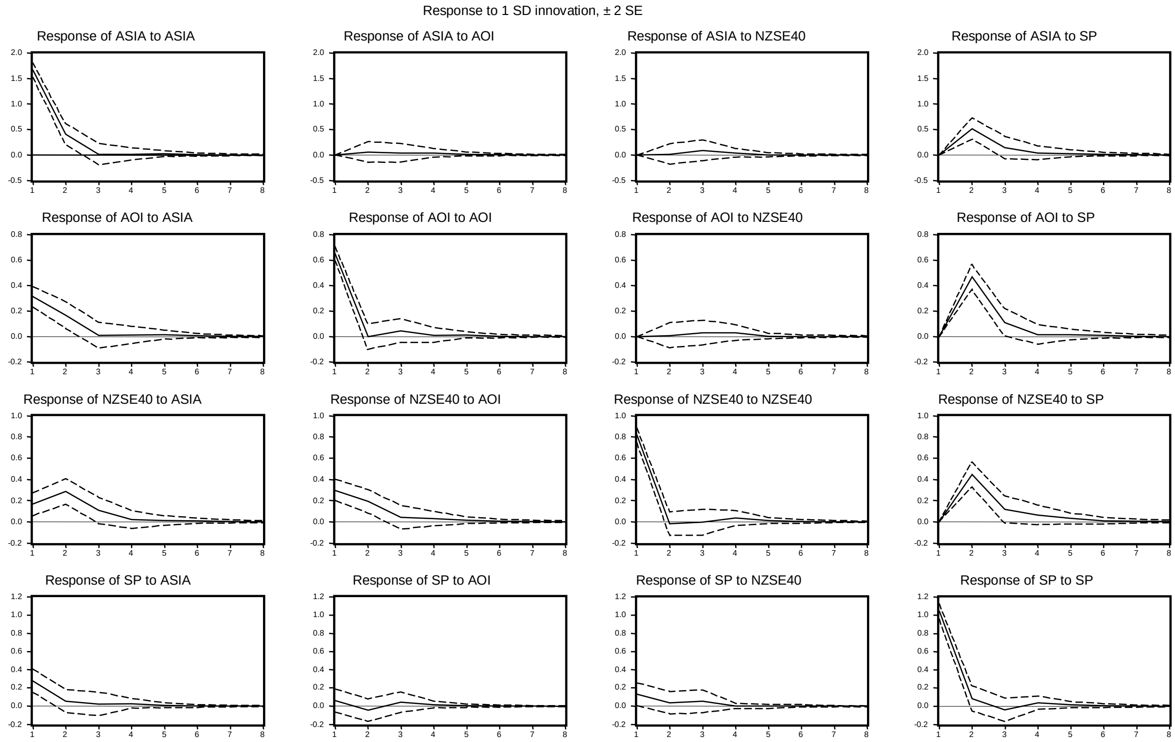


Table 10
Stock returns variance decompositions, Asian crisis

Period	**SE**	**Asia**	**AOI**	**NZSE40**	**S&P 500**
Asia: MSCI Far East Free excluding Japan					
1	1.663163	100.0000	0.000000	0.000000	0.000000
2	1.788953	91.58451	0.102682	0.008993	8.303816
5	1.799454	90.55363	0.216412	0.312136	8.917818
All Ordinaries Index					
1	0.719485	18.65428	81.34572	0.000000	0.000000
2	0.873748	16.27916	55.15806	0.007574	28.55521
5	0.883768	15.96006	54.22948	0.237500	29.57297
NZSE40					
1	0.882700	3.579450	11.56667	84.85388	0.000000
2	1.049160	9.988225	11.59553	60.09029	18.32595
5	1.065953	10.74370	11.47999	58.34329	19.43302
S&P 500					
1	1.085633	6.496993	0.331497	1.459383	91.71213
2	1.091870	6.663517	0.485786	1.559626	91.29107
5	1.085633	6.496993	0.331497	1.459383	91.71213

Figure 11

Impulse responses for world crisis stock returns VAR

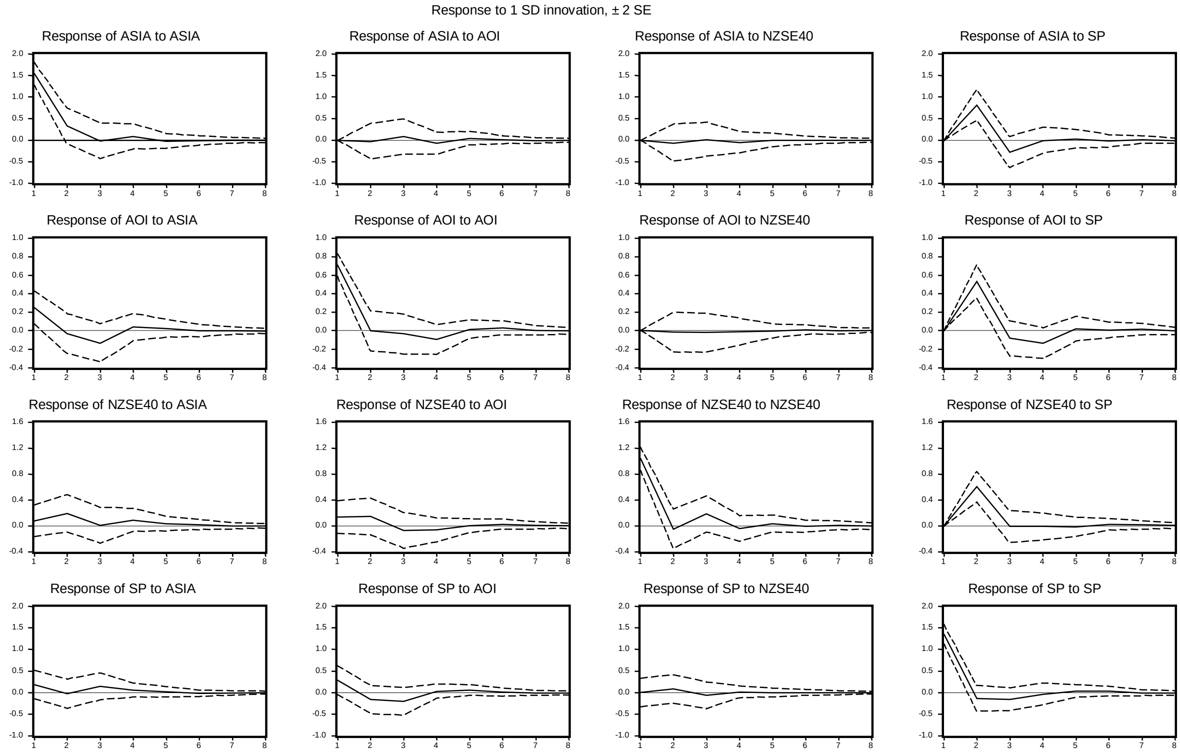


Table 11
Stock returns variance decompositions, world crisis

Period	**SE**	**Asia**	**AOI**	**NZSE40**	**S&P 500**
Asia: MSCI Far East Free excluding Japan					
1	1.534870	100.0000	0.000000	0.000000	0.000000
2	1.768751	78.67906	0.027567	0.130425	21.16295
5	1.797566	76.41886	0.488140	0.210869	22.88213
All Ordinaries Index					
1	0.750888	10.94246	89.05754	0.000000	0.000000
2	0.920059	7.408600	59.31890	0.027421	33.24508
5	0.950736	9.129159	56.74683	0.098782	34.02523
NZSE40					
1	1.046186	0.528573	1.626280	97.84515	0.000000
2	1.232038	2.760748	2.523090	70.71275	24.00342
5	1.254200	3.209581	3.057576	70.51633	23.21651
S&P 500					
1	1.389697	1.732727	4.244640	0.000487	94.02215
2	1.408422	1.721199	5.481639	0.360270	92.43689
5	1.444319	2.812388	7.475059	0.546025	89.16653

Figure 12

Impulse responses for post-crisis stock returns VAR

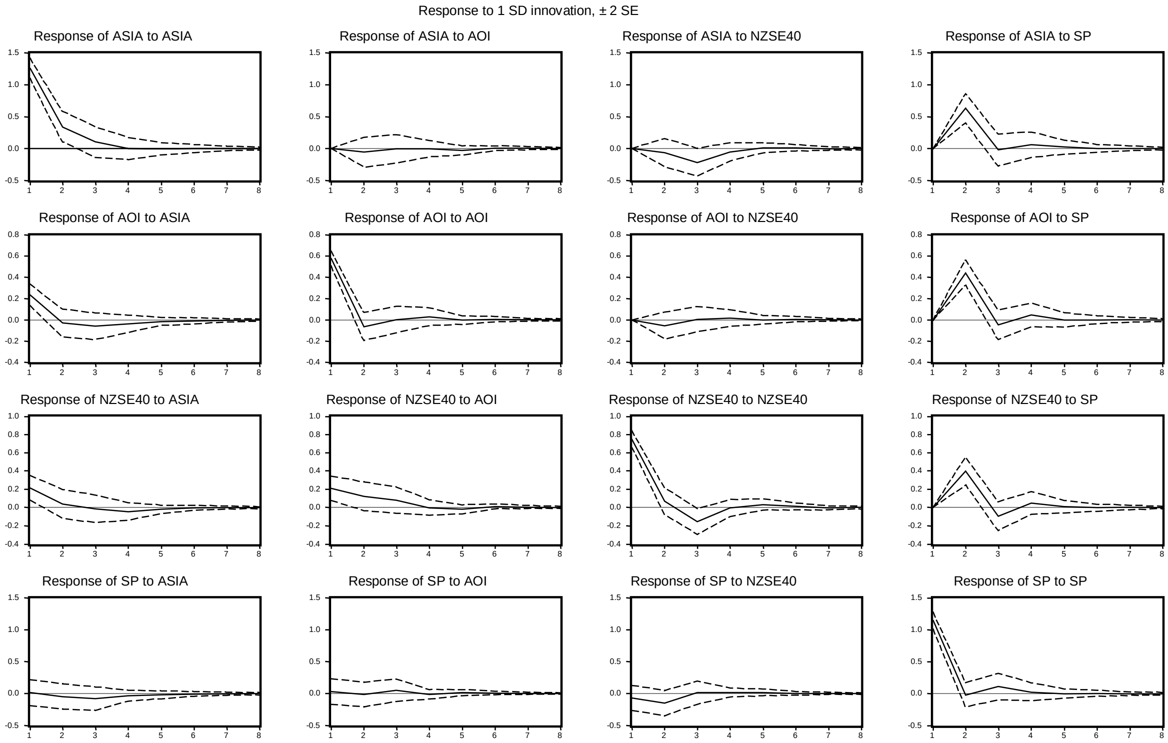


Table 12

Stock returns variance decompositions, post-crisis

Period	**SE**	**Asia**	**AOI**	**NZSE40**	**S&P 500**
Asia: MSCI Far East Free excluding Japan					
1	1.255178	100.0000	0.000000	0.000000	0.000000
2	1.449960	80.50739	0.143763	0.203534	19.14531
5	1.472692	78.52142	0.186564	2.505483	18.78654
All Ordinaries Index					
1	0.621094	14.28146	85.71854	0.000000	0.000000
2	0.767114	9.491655	56.85340	0.477399	33.17755
5	0.773912	10.18582	56.00659	0.523479	33.28412
NZSE40					
1	0.807679	7.041972	6.734723	86.22330	0.000000
2	0.911771	5.691949	7.033684	68.24758	19.02679
5	0.936746	5.708620	7.430989	67.55056	19.30983
S&P 500					
1	1.146743	0.013412	0.067533	0.349749	99.56931
2	1.157855	0.176475	0.087614	2.041724	97.69419
5	1.168442	0.773487	0.299874	2.054634	96.87200

The impulse responses shown in Figures 9–12, and the variance decompositions in Tables 9–12, are based on the recursive identification scheme discussed above. We cannot be completely certain that we have identified true structural innovations using this scheme. However, we are confident that a different ordering within a recursive scheme would not appreciably affect the results. The impulse responses and variance decompositions derived using other possible orderings are very similar to those presented here.[15] In particular, even when the US variable (S&P 500) was ordered before the other variables, allowing it to affect all other variables contemporaneously, the impulse responses of the other variables to an innovation in the S&P 500 were still tent-shaped, with the contemporaneous responses being close to (and almost always insignificantly different from) zero. A similar result applied for the bond and foreign exchange market results presented in the following sections.

The variance decompositions for the four periods show that own market innovations are the most important, although the S&P 500 has a significant impact on the Australian and New Zealand indices in all periods. The effect of the Asian market variable on Australian and New Zealand stocks was also fairly important, particularly during the Asian crisis period. There was some apparent cross-determination between the Australian and New Zealand markets, although this was not robust to different relative orderings. As expected, the S&P 500 was virtually entirely driven by own market innovations, although the contribution of the Asian variable in the crisis period was higher than at other times.[16]

When we examine each of the sub-periods individually, however, we obtain results that conflict with the usual intuition about the spillover of financial market volatility, i.e. that transmission of volatility from one market to another should be greater in times of crisis than in more normal times. The implied response of Australian and New Zealand stocks to an innovation from the Asian series was *proportionately smaller* in both the Asian and world crisis periods than in the pre-crisis period. The impulse response peaked at around 0.2 percentage points in both the pre-crisis and Asian crisis periods, even though the size of a one-standard-deviation innovation in the Asian series was substantially larger in the Asian crisis period than the pre-crisis period. Moreover, the reaction in the post-crisis period was similar to the reaction in the Asian crisis, and greater than in the world crisis period.

4.2 Bond markets

Figure 14 suggests that EMBI Global Constrained had a small and marginally significant impact on Australian and New Zealand bond returns during the Asian crisis period. However, the greatest reaction of Australian and New Zealand bond returns to the Asian series was in the pre-crisis period.[17] This result may be due to the EMBI series picking up the effects of the Japanese and European markets on Australian and New Zealand bond yields. Previous work has suggested some role for these other markets, independent of the US market, in explaining bond market movements in Australia (Kortian and O'Regan (1996)). Since these markets are omitted from our estimates, it may be that the EMBI series is picking up innovations from those markets during the 1994 bond market sell-off. If the Japanese and European market had affected Asian markets as well as the Australian and New Zealand markets, then our identification approach will capture this as Australian and New Zealand returns being affected by Asian returns.

There does not appear to be an indirect response to Asia via the US market. Overnight developments in US bond markets had a strong effect on Australian and New Zealand bond returns, accounting for

---

[15] There are 4!=24 possible orderings for a four-variable VAR; if Australia and New Zealand are treated as a block (i.e., kept together but with potentially different ordering within the block) there are twelve. The results for the other orderings are available from the authors.

[16] We have omitted the responses of the S&P 500 to other variables from the impulse response graphs as they are very close to zero.

[17] In both the pre-crisis and the Asian crisis period, the point estimate is around 0.01, although the size of a one-standard-deviation EMBI shock in the Asian crisis period was somewhat larger.

15–30% of their variability in the Asian crisis period, 40% in the world crisis period and 66% in the post-crisis period. However, during the Asian crisis (and the world crisis), bond market volatility in

Figure 13

Impulse responses for pre-crisis bond returns VAR

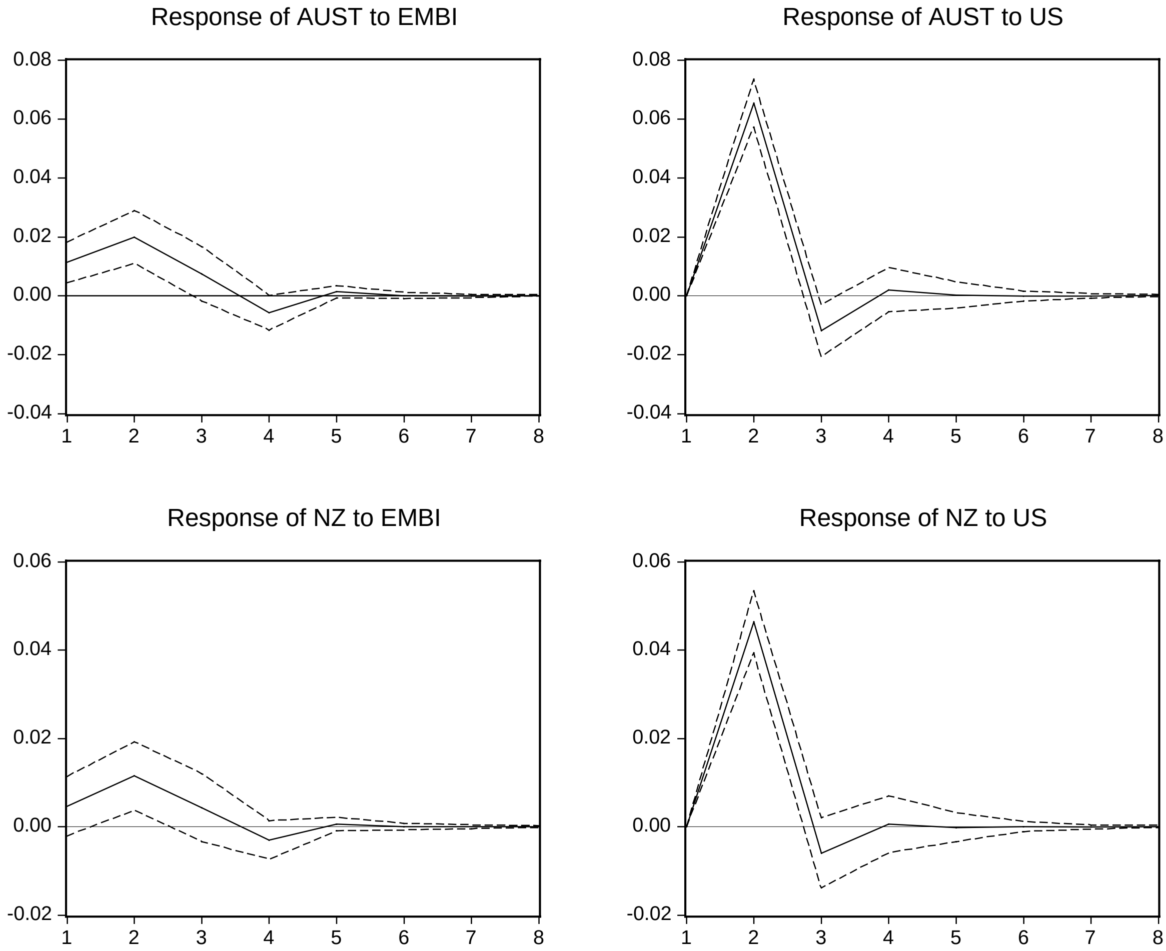


Table 13

Bonds variance decompositions, pre-crisis

Period	SE	AUST	NZ	US	EMBI
Australian bond futures					
1	0.085200	98.22205	0.000000	0.000000	1.777947
2	0.109599	59.72717	0.232840	35.65331	4.386683
5	0.110739	58.56773	0.303433	36.10057	5.028259
New Zealand bond futures					
1	0.080857	18.26934	81.40192	0.000000	0.328740
2	0.094819	13.60097	60.79360	23.90294	1.702492
5	0.095185	13.52368	60.36892	24.11231	1.995087

Figure 14

Impulse responses for Asian crisis bond returns VAR

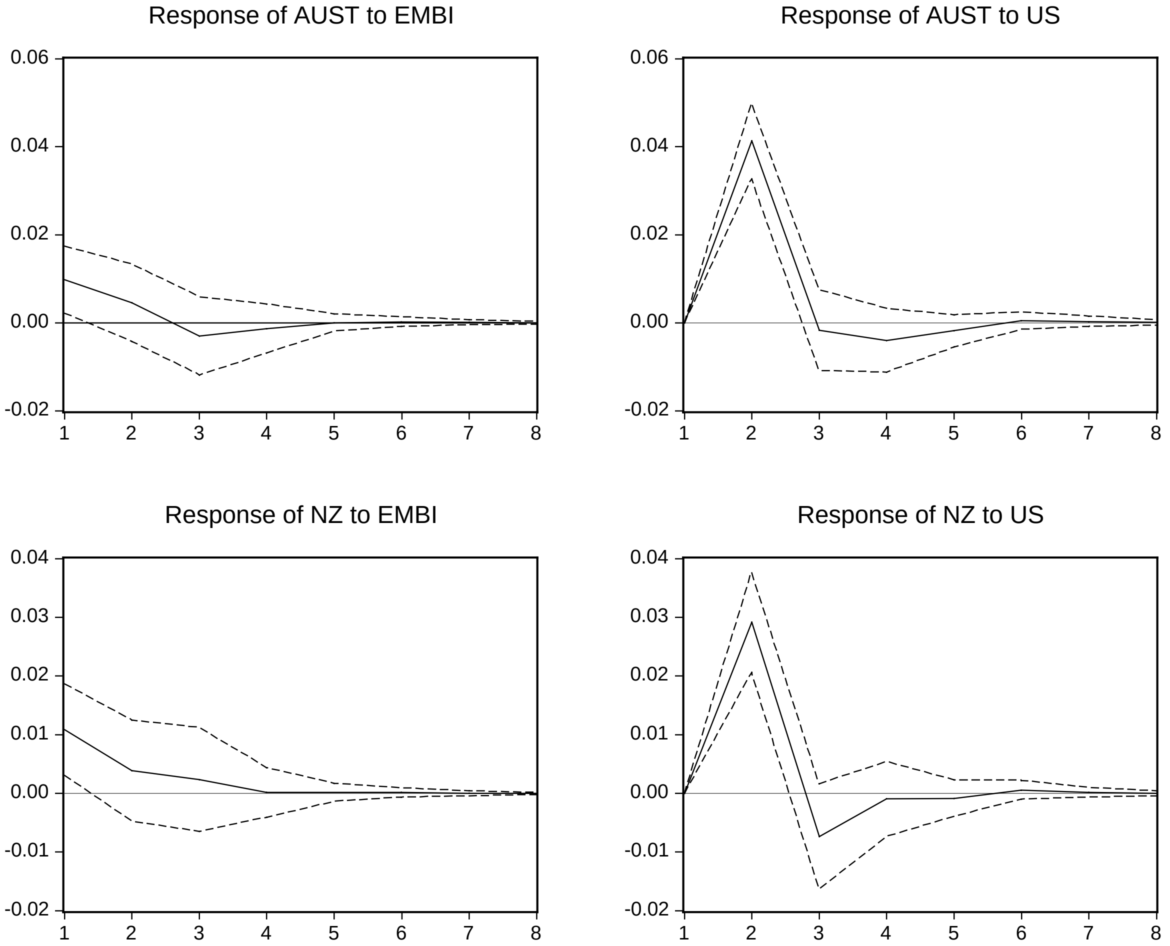


Table 14

Bonds variance decompositions, Asian crisis

Period	**SE**	**AUST**	**NZ**	**US**	**EMBI**
Australian bond futures					
1	0.062261	97.52979	0.000000	0.000000	2.470210
2	0.075049	67.28687	0.383318	30.26396	2.065851
5	0.075528	67.09444	0.408975	30.26936	2.227224
New Zealand bond futures					
1	0.066856	15.32406	82.04628	0.000000	2.629657
2	0.073199	12.83317	68.86906	15.82690	2.470865
5	0.073665	12.76430	68.03889	16.65592	2.540887

Figure 15

Impulse responses for world crisis bond returns VAR

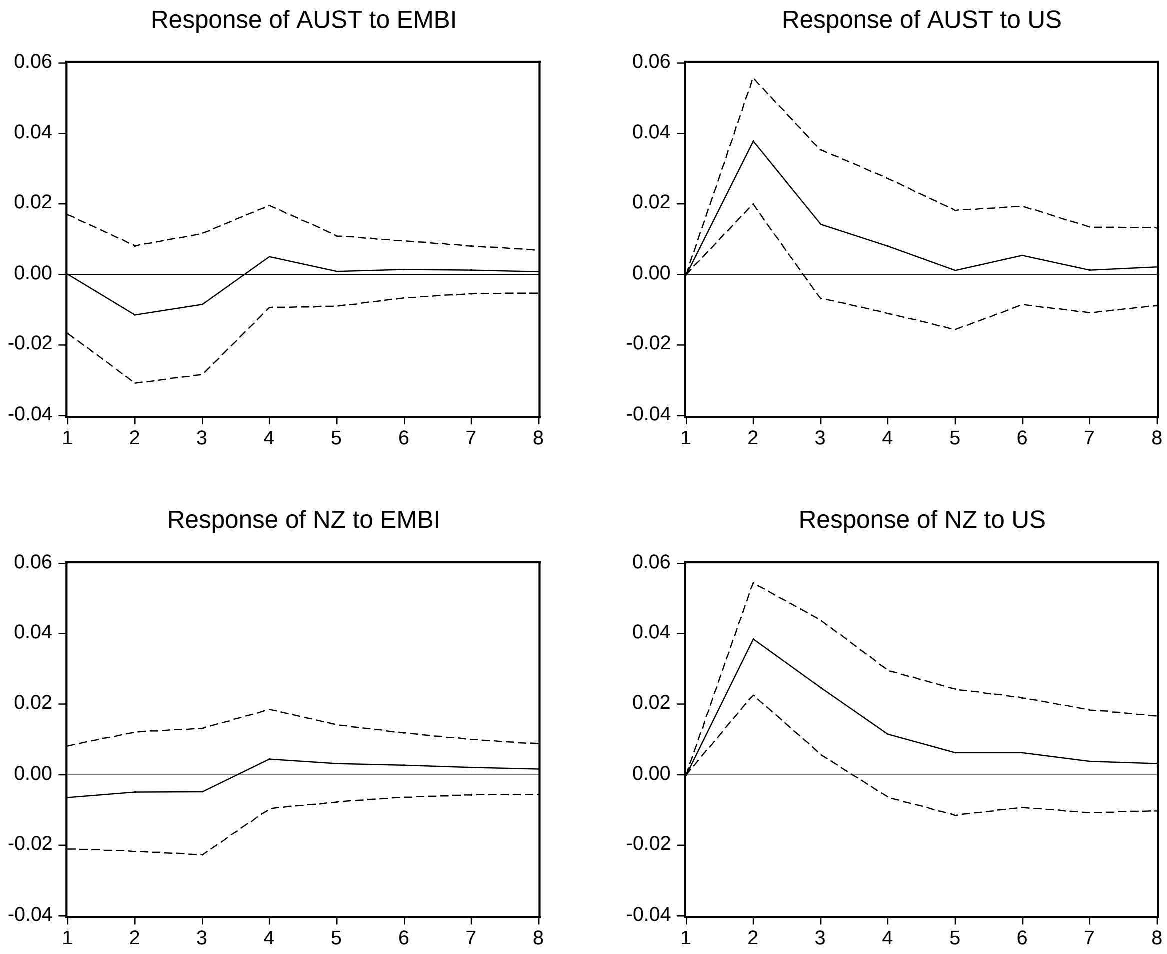


Table 15

Bonds variance decompositions, world crisis

Period	SE	AUST	NZ	US	EMBI
Australian bond futures					
1	0.064735	99.99992	0.000000	0.000000	7.96E-05
2	0.078880	74.58906	0.275470	23.01557	2.119898
5	0.081283	70.27160	0.514577	25.74554	3.468275
New Zealand bond futures					
1	0.056596	34.44071	64.26665	0.000000	1.292638
2	0.069234	23.40149	44.42332	30.81652	1.358669
5	0.075197	20.23925	37.71642	39.95933	2.084998

Figure 16

Impulse responses for post-crisis bond returns VAR

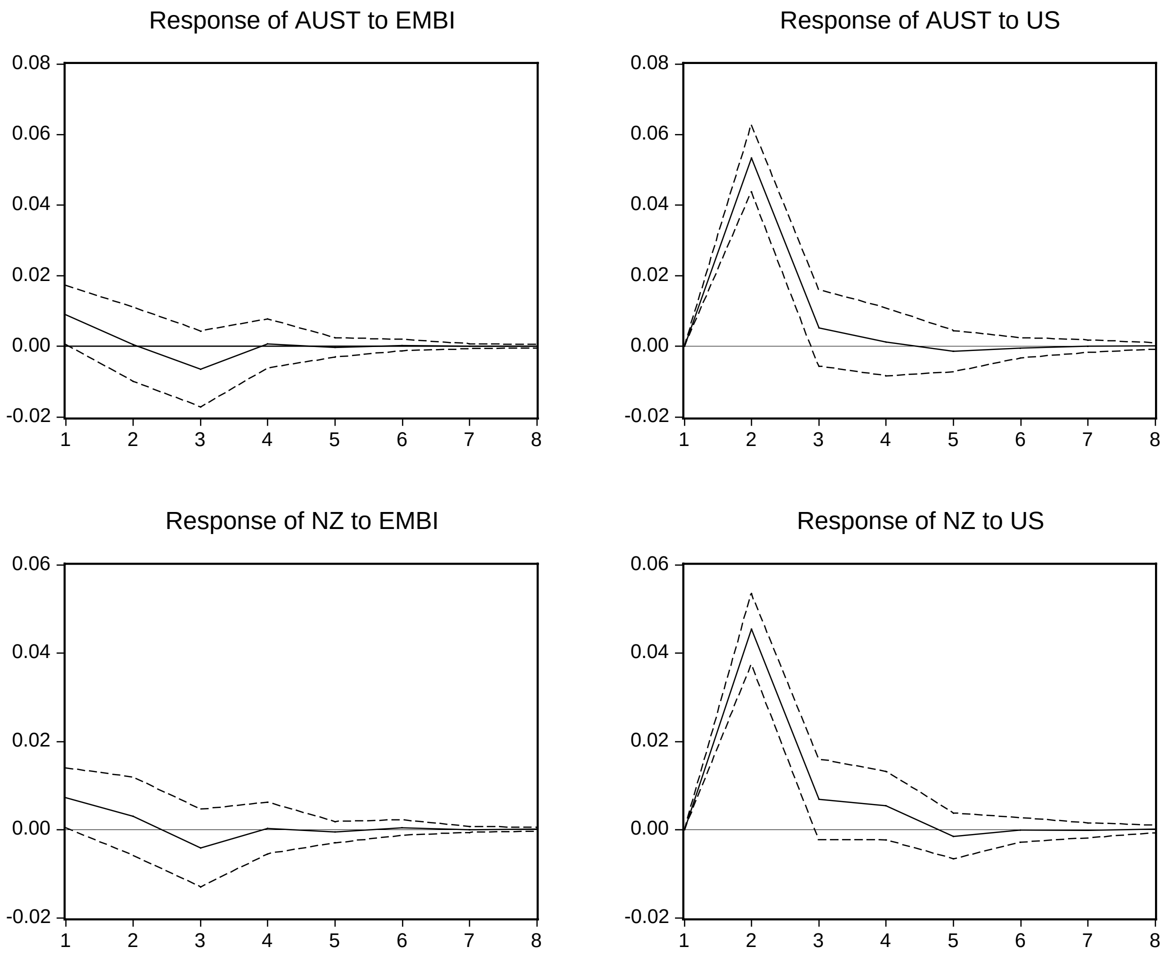


Table 16

Bonds variance decompositions, post-crisis

Period	SE	AUST	NZ	US	EMBI
Australian bond futures					
1	0.049935	99.16257	0.000000	0.000000	0.837429
2	0.090021	31.04368	0.838819	67.54907	0.568431
5	0.091860	30.09983	2.325278	66.23066	1.344231
New Zealand bond futures					
1	0.038648	33.54632	66.44916	0.000000	0.004515
2	0.069849	10.40950	21.72016	67.35815	0.512196
5	0.071256	10.30448	22.30867	65.30996	2.076893

Asia, as proxied by EMBI, accounted for an insignificant part of the variation in the US market (less than 1%).[18]

18 In this section and the section presenting results for the bilateral exchange rates, we omit the impulse responses and variance decompositions for the US and Asian variables from the graphs and tables. These results are available from the authors (but see also Figures and Tables 13–20).

There are a number of possible reasons for this smaller response to Asian crisis events than is the case for stocks. In particular, bond yields are determined primarily by expectations of inflation and (domestic) real interest rates. Therefore, bond returns should be less affected by corporate sector and trade developments than are other markets, and so the economic linkages rationale for contagion between asset markets (Lowell et al. (1998)) is not as important. This would tend to result in a more muted reaction in bond markets than for stocks and, particularly, exchange rates.

4.3 Exchange rates

There was a clear reaction of the Australian dollar/US dollar and New Zealand dollar/US dollar to movements in Asian markets during the Asian crisis (Figure 18). This response was much more obvious than in the other two markets. Exchange market movements in Asia were significant during the Asian crisis, accounting for just under 8% of the variation in the Australian dollar/US dollar rate, and around 5.5% of the New Zealand dollar/US dollar.[19] There was also a significant impact on the New Zealand dollar/US dollar rate in the pre-crisis period. In the other periods, the impulse responses were not more than two standard deviations from zero (although nearly so for the Australian dollar/US dollar in the world crisis; see also Figures and Tables 17–20). While this might partly reflect the poor fit of the linear model – evidenced by the large error bands in most periods – it makes the contrast with the Asian crisis period even more striking.

As might be expected from the results in Section 3.2, another feature of these results is the increasing importance of the CRB index in explaining daily movements in both the Australian dollar/US dollar and New Zealand dollar/US dollar exchange rates. Since Australia's and New Zealand's exports have tended to become more diverse over time, rather than more concentrated in commodities, this result cannot reflect changing fundamentals. In any case, the extent of the change in exchange rate behaviour is probably too dramatic to be explained by a shift in the composition of exports. Moreover, the composition of the CRB index is not a particularly good match with the commodities exported by Australia and New Zealand, perhaps suggesting that short-term movements in these exchange rates have become *less* aligned with genuine fundamentals over time. This type of development may be evidence that financial market integration brings an increased proportion of less-informed traders to regional markets, who may look to indicator variables with little information content – but high-frequency availability – in forming their views and trading strategies. In this context, the theoretical findings of Calvo and Mendoza (1999) seem particularly pertinent. On the other hand, the increasing importance of the CRB index may simply reflect that the shocks to commodity prices were concentrated in the components of the index most relevant to Australian and New Zealand exports, despite the index as a whole being an imperfect measure of prices of these exports.

4.4 Interpretation

Our results indicate that responses to crises can vary between asset classes. There is not a uniform notion of increased uncertainty driving a uniform result: rather, each asset class is influenced by both common and market-specific factors. In addition, there are differences between the results in the Asian crisis and world crisis periods, which may reflect the different nature of shocks hitting Australian and New Zealand financial markets in the two periods. The Asian crisis countries are largely commodity importers and significant trading partners of Australia and New Zealand; the countries in financial distress in the world crisis period – primarily Russia and Brazil – are commodity exporters with little bilateral trade with Australia and New Zealand, although they are competitors in third markets.

The VAR estimates imply that Australian and New Zealand stock and (to a lesser extent) bond markets were *less* affected by movements in Asian markets during the crises than at other times. That is, spillover from these markets in crisis to unrelated markets appears to be weaker than it is between

[19] The large fraction of New Zealand dollar/US dollar variability accounted for by the Australian dollar/US dollar rate is an artefact of our recursive ordering identification scheme, and may reflect that the Australian and New Zealand dollars tend to be traded as a bloc.

markets that are already in similar environments. Put (very loosely) in the language of the "heat wave" versus "meteor showers" literature (Engle et al. (1990)), these markets do not react more to "meteors" during crises – they are simply being hit by bigger meteors then. However, these results could partly reflect the type of information captured by a regional market index. Financial market returns depend on common – or "global" – shocks, regional shocks and country or "country-specific" (idiosyncratic)

Figure 17

Impulse responses for four-variable exchange rate returns VAR, pre-crisis

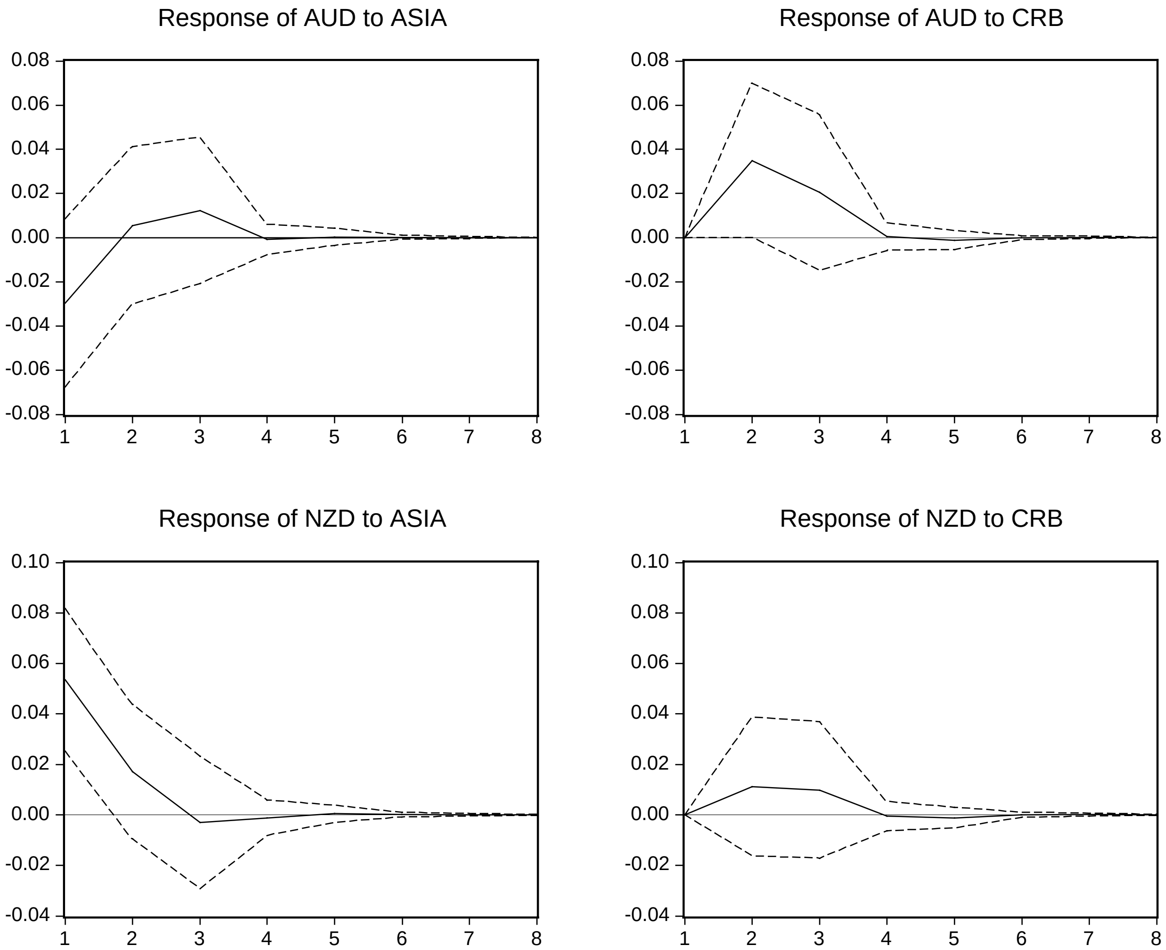


Table 17

Exchange rate variance decompositions, pre-crisis

Period	SE	A$	NZ$	CRB	ASIA
A$/US$					
1	0.467578	99.60259	0.000000	0.000000	0.397409
2	0.469042	99.03066	0.005615	0.555170	0.408558
5	0.470090	98.59864	0.184398	0.740829	0.476135
NZ$/US$					
1	0.359507	21.97531	75.80229	0.000000	2.222405
2	0.360846	22.20538	75.26712	0.096069	2.431432
5	0.363045	22.13094	75.28926	0.169456	2.410339

Figure 18

Impulse responses for four-variable exchange rate returns VAR, Asian crisis

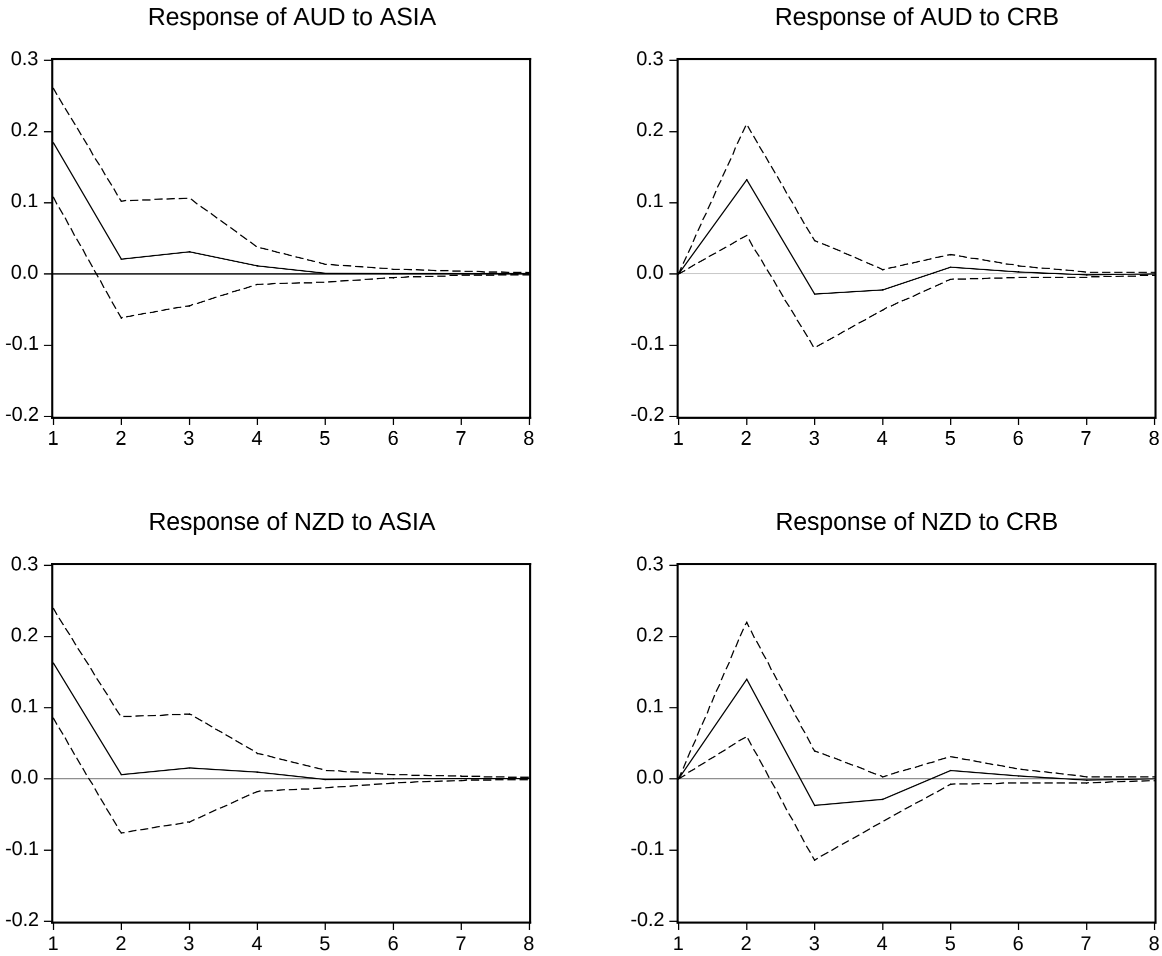


Table 18
Exchange rate variance decompositions, Asian crisis

Period	**SE**	**A$**	**NZ$**	**CRB**	**ASIA**
A$/US$					
1	0.659907	92.22623	0.000000	0.000000	7.773767
2	0.673344	88.59132	0.002285	3.851255	7.555144
5	0.680216	87.78647	0.500349	4.081009	7.632175
NZ$/US$					
1	0.671578	54.82092	39.36661	0.000000	5.812462
2	0.687084	52.45903	37.85542	4.126116	5.559432
5	0.696805	52.63966	37.39013	4.501398	5.468811

Figure 19

Impulse responses for four-variable exchange rate returns VAR, world crisis

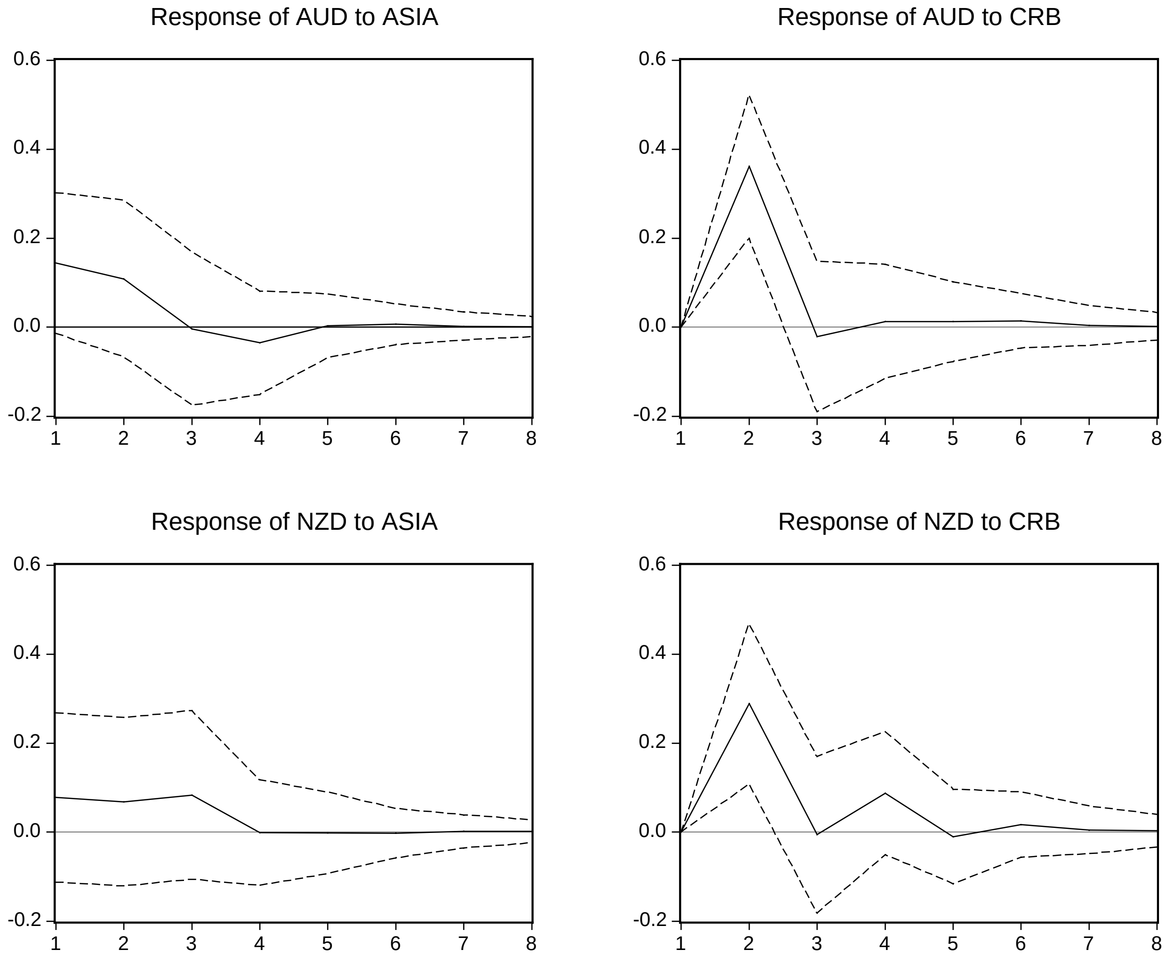


Table 19

Exchange rate variance decompositions, world crisis

Period	**SE**	**A$**	**NZ$**	**CRB**	**ASIA**
A$/US$					
1	0.645511	95.02422	0.000000	0.000000	4.975782
2	0.753993	70.71614	0.618036	22.94515	5.720675
5	0.761877	70.34418	1.233740	22.60467	5.817406
NZ$/US$					
1	0.759300	58.14465	40.80457	0.000000	1.050773
2	0.821129	50.83597	35.23830	12.35003	1.575700
5	0.850081	52.00823	32.95247	12.61087	2.428423

Figure 20

Impulse responses for four-variable exchange rate returns VAR, post-crisis

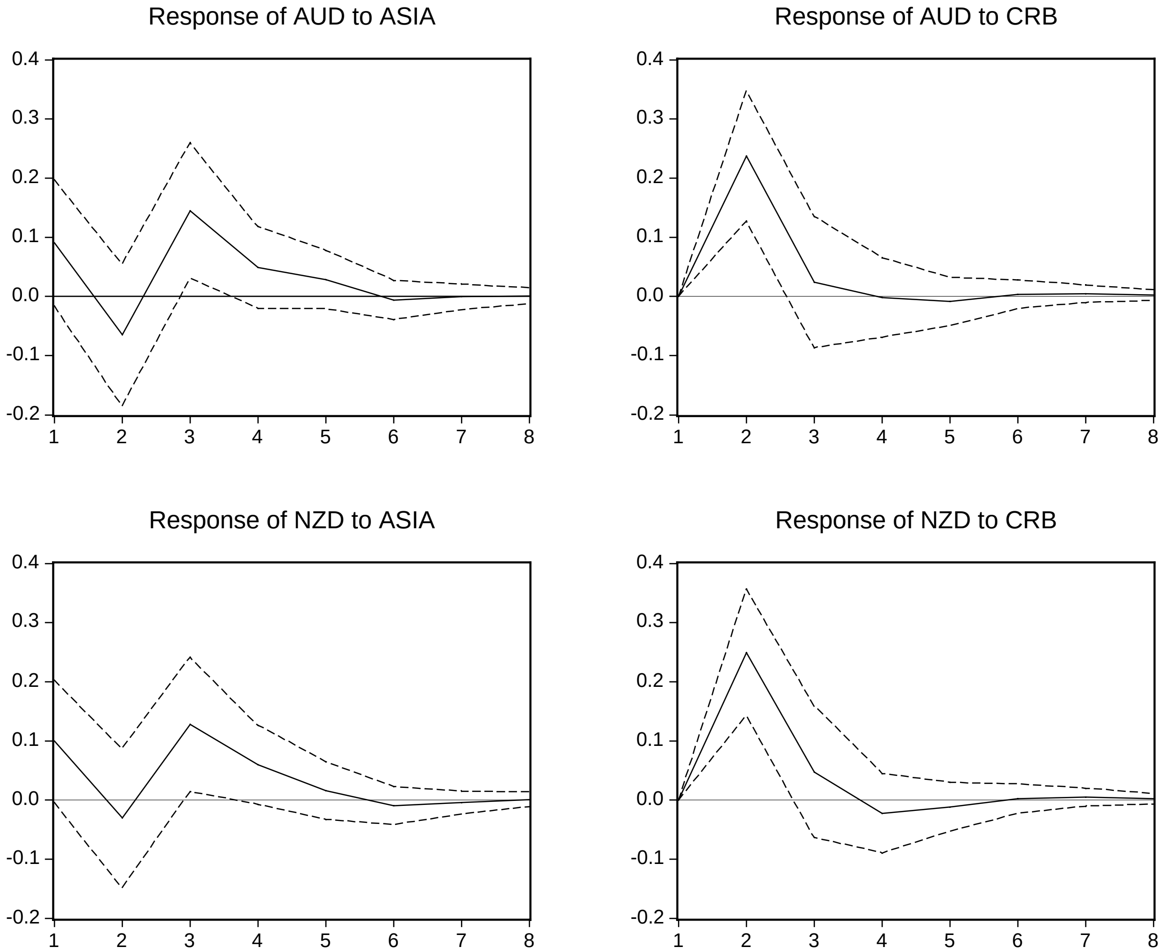


Table 20
Exchange rate variance decompositions, post-crisis

Period	SE	A$	NZ$	CRB	ASIA
A$/US$					
1	0.608434	97.79013	0.000000	0.000000	2.209869
2	0.656944	84.05403	0.025924	13.04857	2.871475
5	0.678600	79.40476	0.259016	12.37287	7.963361
NZ$/US$					
1	0.588463	57.72139	39.42747	0.000000	2.851140
2	0.640428	48.84315	33.33962	15.18252	2.634709
5	0.661120	46.46302	31.55317	14.91386	7.069949

shocks. By using a regional index, we are effectively averaging across country-specific shocks, so that most of the information in the series will reflect regional and global shocks. The global shocks are important for Australia and New Zealand, but this should be interpreted as all markets being affected by a common (global) shock, rather than spillover of an Asian region shock to Australia and New Zealand.

During the crisis periods, however, the Asian market variables incorporate idiosyncratic (country-specific) and regional shocks that were much larger than in non-crisis periods. Also, although country-specific shocks would ordinarily tend to average out and thus not show up in a regional index, this may not have been the case during the Asian crisis, as shocks were disproportionately negative in that period. These Asia-specific shocks may be less important to Australian and New Zealand markets than the global shocks also captured in the Asian data. Therefore, the estimated coefficients on the stock price indices during the Asian crisis period might have been smaller because the series contained *proportionally less* information relevant to markets in Australia and New Zealand.

By contrast, spillover of financial market volatility to *exchange rates* was greater during the crises than at other times. This difference is an example of the tendency for the asset class to matter more in determining spillover than did the country where the market was located. Indeed, the importance of Asian export markets for Australia and New Zealand may imply that Asia-specific shocks are *more* important than other shocks for exchange rates.

These results are not necessarily conclusive, as they might have some limitations. In particular, by using linear VAR econometric models, we have ignored the well-documented ARCH characteristics seen in most financial data sets, including the ones used in this paper. On the other hand, our investigations suggest that accounting for these characteristics does not affect the essential results.

5. Conclusion

Our results represent a first pass at examining the spillover of financial returns across markets, specifically the reactions by Australian and New Zealand markets to news about financial crises in other countries. We find that news events and movements in Asian financial markets had noticeable effects on financial markets in Australia and New Zealand. These events were not the *primary* determinant of Australian and New Zealand financial returns during the crises, however. During the Asian crisis, domestic developments generally accounted for more than half of the variation in Australian and New Zealand returns. The few cases where domestic shocks accounted for less than half of the total variation in daily returns reflected the apparent common shock affecting both the Australian dollar and New Zealand dollar exchange rates. In the post-crisis period, the US bond market also had a strong influence on its Australian and New Zealand counterparts.

Developments in US markets were more important than Asian market returns for Australian and New Zealand stocks and bonds. This result may be another example of the close relationship between US and Australian economic variables seen in other studies (Gruen and Shuetrim (1994), de Roos and Russell (1996) and Kortian and O'Regan (1996)). Moreover, the results from Section 3 suggest that stock markets in Australia and New Zealand seem to have reacted to Asian news with a lag. This may indicate that market participants wait until they observe the reaction in the United States before responding to the news. If true, this finding suggests that participants in financial markets do not process information efficiently. On the other hand, the reactions to movements in Asian financial markets, shown in Section 4, did indicate a contemporaneous relationship.

The results show that different asset classes can react differently to the same events. The bond markets were little affected by developments in Asia, while the stock markets displayed a (sometimes delayed) clear reaction; exchange rates were the most affected by events in Asia. These differences probably reflect that, even though financial markets react to the same set of information about fundamentals, the relative importance of particular aspects of fundamentals can vary greatly across asset classes. For example, returns on bonds are largely driven by expectations of future developments in inflation and monetary policy. The implications of the Asian news events for Australian and New Zealand inflation (via exchange rate depreciations) may have been offset by a "flight to quality", and by expectations that the world real interest rate had fallen in response to the contraction in Asian demand. In addition to expected inflation and interest rates, stock market returns reflect corporate profitability and indicators of world demand such as commodity prices. Therefore, a downturn in Asia and elsewhere would reduce expected returns on Australian and New Zealand stocks.

The currencies of the two countries were the asset class most affected by Asian news events. This supports the idea that trade developments, such as recessions in trading partner nations, affect exchange rates more than they affect returns on other assets. The economic contractions in Asia would have reduced demand for differentiated products exported to Asia, and also tended to reduce commodity prices. Consequently the bilateral exchange rates of the Australian dollar and New Zealand dollar against the US dollar depreciated through the Asian crisis period.

The world crisis period, on the other hand, was characterised by small appreciations in the currencies. These were despite the large falls at the end of August 1998, which largely reflected developments in global financial markets and the positions of highly leveraged traders. This seems in line with the different implications of the world crisis for commodity prices, given that the countries newly affected then tended to be commodity exporters. We would therefore expect smaller depreciations in other commodity exporters' currencies, since depreciation of a competitor's currency will only affect commodity prices in US dollar or own currency terms if the competitor responds by increasing its supply of commodities onto the world market. This effect was offset by the effects of market participants unwinding the short positions in the Australian dollar and New Zealand dollar built up towards the end of the Asian crisis period, resulting in a net appreciation.

We did not find any evidence of significant differences between the reactions of Australian and New Zealand markets, despite the differences in the monetary policy stances and operational regimes in those countries. This may reflect the similarities in their other fundamentals and in particular that the two currencies tend to be traded as a bloc.

In essence, our results suggest that financial markets may be buffeted by shocks spilling over from other markets in crisis. Even when markets are not dragged into crises, some spillover of shocks clearly occurs for at least some asset classes. This can sometimes occur regardless of domestic fundamentals, as evidenced by the exchange rate volatility in the world crisis period being at least as high as – if not higher than – in the Asian crisis period. This occurred even though the Asian crisis countries are more important trade partners for Australia and New Zealand than the countries dragged into the world financial crisis of late 1998, and, again, probably reflects the turmoil in markets generally, rather than reactions to crises in specific countries.

Appendix: Chronology of major events in the Asian crisis

Date	**Event**	**Type of news**
1997		
15 May	Thailand, after a week of selling pressure and massive intervention in the forward markets, announces wide-ranging capital controls aimed at segmenting the onshore and offshore markets.	bad
27 June	The BoT suspends the operations of 16 troubled finance companies and orders them to submit merger or consolidation plans.	bad
2 July	Floating of the Thai baht (baht devalues by 15% in onshore markets, 20% in offshore markets). Pressure spreads to the Philippine peso, Malaysian ringgit and Indonesian rupiah.	bad
11 July	BSP announces the peso will float in a wider range, abandoning the de facto peg. BI widens the rupiah trading band from 8% to 12%.	bad
14 July	BNM is reported as abandoning the defence of the ringgit.	bad
28 July	Thai government requests IMF assistance.	bad
5 August	Thailand suspends a further 42 troubled finance companies.	bad
14 August	Indonesia abandons the rupiah trading band. The rupiah depreciates by 4%.	bad
20 August	Thailand and the IMF agree on a US$ 17 billion financial stabilisation package.	good
27 August	Malaysia imposes trading restrictions on the stock market including an effective ban on short selling.	bad
29 August	BI introduces selective credit controls on rupiah trading.	bad
8 October	Indonesia announces it will seek IMF assistance.	bad
17 October	Malaysia announces an austerity budget. Authorities stop supporting the new Taiwan dollar, which falls by 6%. Pressure on Hong Kong dollar and equity markets intensifies. Review of Thai emergency funding.	bad
20–23 October	Financial turbulence in Hong Kong. Hang Seng index falls by 23% in four days. Overnight interest rates rise from 7% to around 250%. S&P downgrades Korea's and Thailand's sovereign ratings.	bad
27 October	The Dow Jones loses 554 points, following the crash in the Hang Seng. Equity markets in Brazil, Argentina and Mexico see their biggest single-day losses, as the crisis ripples across the globe.	bad
28 October	Russian equity prices decline by 23%.	bad
31 October	Bank resolution package announced in Indonesia, resulting in the closure of 16 troubled private banks. Leads to a depositor run on others. After intense pressure on the real, the Central Bank of Brazil doubles the central bank intervention rate to 43%.	bad
5 November	IMF standby credit for Indonesia of US$ 10.1 billion approved; US$ 3 billion made available immediately.	good
10 November	In Thailand, opposition leader Chuan Leekpai takes over as Prime Minister. In Russia, interest rates raised by 7 percentage points and authorities announce that the intervention band for the rouble will be widened from ±5% to ±15%.	bad
17 November	Korea abandons defence of the won.	bad
18 November	Korean finance minister resigns. Authorities announce a reform package.	bad
20 November	Daily fluctuation band for the Korean won widened from ±2¼% to ±10%.	bad
21 November	Korea requests IMF assistance.	bad
3 December	Korea and the IMF agree on a US$ 57 billion financial assistance package.	good
8 December	Thai authorities close 56 of the suspended finance companies.	bad
16 December	Floating of the Korean won.	bad
23 December	Rating agencies downgrade Korea's sovereign rating to speculative grade. The won falls to nearly 2,000 to the US dollar.	bad

24 December	IMF and other lenders announce speeding-up of disbursement of financial assistance and that international commercial banks will roll over short-term debts owed by Korean financial institutions.	good
30 December	Foreign banks agree to roll over Korean debt.	good
1998		
2 January	Indonesia announces plans to merge four out of seven state-owned banks. Malaysia announces plans for mergers of finance companies.	good
6 January	Indonesian budget introduced: badly received by financial markets.	bad
13 January	Thailand amends law for foreign investors in banks to be reclassified as domestic companies, allowing them to hold property.	good
15 January	Indonesia and the IMF announce agreement on revised economic programme aimed at strengthening and reinforcing the ongoing IMF-supported programme.	good
16 January	International lenders officially agree to roll over Korean short-term bank debt.	good
20 January	Thailand allows full foreign ownership of securities firms.	good
27 January	Indonesia guarantees commercial bank obligations, allows overseas investments in local banks and announces a freeze on debt payments.	good
29 January	Agreement between Korea and its external creditors to exchange $US 24 billion of short-term debt for government-guaranteed loans at 2¼–2¾ percentage points over six-month LIBOR.	good
30 January	Thailand lifts currency restrictions, reunifying the spot market.	good
9–10 February	Indonesia's plan to create a currency board is opposed by the IMF and several creditor governments, which threaten to withdraw financial assistance.	bad
13 February	IMF Managing Director Camdessus expresses further concern over Indonesia's move to a currency board. He is of the "strong view" that the time for a currency board in Indonesia has "not yet come" because of a number of preconditions.	bad
4 March	In a second review of Thailand's economic programme, the IMF relaxes certain macroeconomic policy targets and approves disbursement of second tranche.	good
10 April	Indonesia signs new letter of intent on economic programme with IMF.	good
21 May	Indonesia's president Suharto resigns.	bad
25 May	The Korean stock market falls to an 11-year low.	bad
1 June	The Thai stock market index, continuing its slide from early March, falls to a 10-year low.	bad
4 June	Indonesian authorities reach an agreement to restructure the external debt of Indonesia's banking and corporate sectors.	good
10 June	Third Quarterly Review of Thailand's assistance programme: indicated restructuring on track.	good
2 July	World Bank approves a US$ 1 billion loan to Indonesia. Loan is part of US$ 4.5 billion pledged by the World Bank in 1997.	good
8 July	S&P affirms its CCC+ rating on the Republic of Indonesia's US$ 400 million yankee bond due in 2006, and the CCC+ long-term foreign currency and B– long-term local currency issuer credit ratings. Outlook is now described as negative.	bad
10 July	Malaysian stock index hits nine-year low.	bad
16 July	IMF approves US$ 1 billion payment and promises another US$ 6 billion to Indonesia.	good
24 July	Moody's cuts Malaysia's foreign currency debt rating to Baa2 from A2. Reasons cited are: the country's recession, its growing debt and lack of clear policy direction in response to the Asian crisis.	bad
4 August	Philippines benchmark stock index slides to its lowest level since April 1993 on continuing loss of confidence in the region.	bad
6 August	Malaysia's sovereign risk rating cut to BBB from A by Thomson BankWatch.	bad
7 August	Singapore stock index reaches a 9.5-year low.	bad
11 August	Agence France-Presse (AFP) reports that the Indonesian government is in default on some of its sovereign debt. The government denies this.	bad
13 August	Moody's and S&P cut ratings for Russian sovereign debt.	bad

14 August	Hong Kong government intervenes in the stock market, purchasing an estimated HK$3 billion in stocks and futures, in an attempt to stop the speculation against the currency.	bad
17 August	Russia allows the rouble to float freely within a corridor between 6.00/9.50 to the US dollar and makes some other changes to Russian financial markets. S&P cuts Russia's long-term foreign currency debt rating to CCC from B–.	bad
25 August	IMF Executive Board approves extended funding arrangement for Indonesia.	good
31 August	S&P downgrades Hong Kong's sovereign credit rating to A, with a negative outlook. The rating agency also cites a decline in Hong Kong's financial strength because of the Asian crisis.	bad

Sources: BIS (1998), Table VII.6, p. 131 and IMF (1998), Box 2.12, p. 49.

Bibliography

Almeida, A, C A E Goodhart and R Payne (1998): "The Effects of Macroeconomic News on High Frequency Exchange Rate Behaviour". *Journal of Financial and Quantitative Analysis*, 33(3), pp. 383–408.

Andersen, T G, T Bollerslev, F X Diebold and P Labys (1999): "The Distribution of Exchange Rate Volatility". Wharton Financial Institutions Center, *Working Paper*, No. 99–08, University of Pennsylvania.

Bank for International Settlements (1998): *68th Annual Report*.

Baig, T and I Goldfajn (1998): "Financial Market Contagion in the Asian Crisis". *IMF Working Paper*, WP/98/155, November.

Baig, T and I Goldfajn (1999): "Financial Market Contagion in the Asian Crisis". *IMF Staff Papers*, 46(2) pp. 167–95.

Calvo, G A and E G Mendoza (1999): "Rational Contagion and the Globalisation of Securities Markets". *NBER Working Paper*, No. 7153.

Campbell, F and E Lewis (1998): "What Moves Yields in Australia?" Reserve Bank of Australia, *Research Discussion Paper*, No. 9808.

Chatfield, C and A J Collins (1980): *Introduction to Multivariate Analysis*. London, Chapman and Hall Ltd.

Cooley, W W and P R Lohnes (1971): *Multivariate Data Analysis*. New York, John Wiley and Sons.

De Roos, N and W Russell (1996): "Towards an Understanding of Australia's Co-movement with Foreign Business Cycles". Reserve Bank of Australia, *Research Discussion Paper*, No. 9607.

Dungey, M (1999): "Contagion in Currency Crises: What do We Mean?" La Trobe University, *mimeo*. Available from http://www.business.latrobe.edu.au/staffhp/mardihp/mardi3~1.htm (accessed 7 September 1999).

Dungey, M and V Martin (1998): "Contagion in the East Asian Currency Crisis". La Trobe University, *mimeo*. Available from http://www.business.latrobe.edu.au/staffhp/mardihp/mardi3~1.htm (accessed 7 September 1999).

Eichengreen, B, A Rose and C Wyplosz (1995): "Exchange Market Mayhem: The Antecedents and Aftermath of Speculative Attacks". *Economic Policy: A European Forum*, 21, pp. 251–312.

Eichengreen, B, A Rose and C Wyplosz (1996): "Contagious Currency Crises: First Tests". *Scandinavian Journal of Economics*, 98(4), pp. 463–84.

Engle, R F, T Ito and W Lin (1990): "Meteor Showers or Heat Waves? Heteroskedastic Intra-Daily Volatility in the Foreign Exchange Market". *Econometrica*, 58(3), pp 525–42.

Fleming, M and J A Lopez (1999): "Heat Waves, Meteor Showers and Trading Volume: An Analysis of Volatility Spillovers in the U.S. Treasury Market". Federal Reserve Bank of San Francisco *Working Papers in Applied Economic Theory*, 99–09.

Fleming, M and E Remolona (1997): "What Moves the Bond Market?" *Federal Reserve Bank of New York Economic Policy Review*, 3(4) pp. 31–50.

Gruen, D W R and G Shuetrim, (1994): "Internationalisation and the Macroeconomy", in P Lowe and J Dwyer (eds.), *International Integration of the Australian Economy*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp. 309–63.

International Monetary Fund (1998): "The Asian Crisis: Capital Markets Dynamics and Spillover, Chronology of Major Events in the Asian Crisis and its Spillover". *IMF World Economic Outlook*, September.

International Monetary Fund (1999): “IMF-Supported Programs in Indonesia, Korea and Thailand: A Preliminary Assessment”. Prepared by T Lane and others, January.

Kaminsky, G L and S L Schmukler (1999): “What triggers market jitters? A chronicle of the Asian Crisis”. *Journal of International Money and Finance*, 18(4), pp. 537–60.

Kim, S-J (1996): “Inflation News in Australia: Its Effects on Exchange Rates and Interest Rates”. *Applied Financial Economics*, 6, pp. 225–31.

Kim, S-J and J Sheen (1998): “International Linkages and Macroeconomic News Effects on Interest Rate Volatility – Australia and the US”. University of Sydney, *Working Papers in Economics*, No. 98–11.

Kim, S-J (1999): “The Short-Term Dynamics of Bond Futures Market Response to New Information: Australian Evidence”. University of New South Wales School of Banking and Finance, *Working Paper*, 1999–03.

Kortian, T and J O’Regan (1996): “Australian Financial Market Volatility: An Exploration of Cross-Country and Cross-Market Linkages”. Reserve Bank of Australia, *Research Discussion Paper*, No. 9609.

Lowell, J, C R Neu and D Tong (1998): “Financial Crisis and Contagion in Emerging Market Countries”. RAND MR–962, available from: http://ftp.rand.org/publications/MR/MR962/MR962.pdf/ (accessed 13 September 1999).

Masson, P (1998): “Contagion: Monsoonal Effects, Spillovers, and Jumps between Multiple Equilibria”. *IMF Working Paper*, WP-98/142.

Roubini, N (1999): “Asia Chronology: Chronology of the Asian Currency Crisis and its Global Contagion”. Available from http://www.stern.nyu.edu/~nroubini/asia/AsiaChronology1.html and http://www.stern.nyu.edu/~nroubini/asia/AsiaChronology1998.html (accessed 20 August 1999).

Silverman, B W (1986): *Density Estimation for Statistics and Data Analysis.* London, Chapman and Hall Ltd.

World Bank (1998): *World Bank Atlas.* Washington DC.

The reaction of Swiss bank stock prices to the Russian crisis

Bertrand Rime[1]

1. Introduction

On 17 August 1998 Russia announced a debt moratorium after several weeks of pressure on the rouble exchange rate and tension on the Russian treasury bill markets. The Russian financial collapse represented one more episode in the financial turmoil that had been affecting emerging market economies since the floating of the Thai baht in mid-1997. The spreading crisis in emerging markets raised concerns about the financial stability of a number of western and Japanese creditor banks. Crisis fears culminated in September 1998 with the near-collapse of the hedge fund LTCM. Some analysts pointed to the risk of contagion among international banks and to the systemic repercussions that the failure of a large creditor bank might have on the domestic banking sector of its home country. The loss of investor confidence led to a 30% fall in the stock markets of the developed countries during the third quarter of 1998.

The issues of contagion and systemic risk have a particular dimension in Switzerland for two reasons. First, the Swiss banking sector is highly concentrated by international standards. This is especially true for the domestic interbank market, where the two big banks represent about 65% of total liabilities. Secondly, the two big Swiss banks are highly involved in international banking and have been significantly affected by the Russian crisis and the LTCM debacle.

In this paper, we try to assess the impact of the Russian moratorium on Swiss banks. Using event study methodology, we compute Swiss bank stock returns for a number of events related to the Russian moratorium. In a second step, we regress each bank's stock returns against dummy variables reflecting the bank's category.

The paper is organised as follows. Section 2 provides a detailed chronology of the Russian crisis. In Section 3 we introduce the event study methodology and the cross-sectional regression model. In Section 4 we present the results of the event study and of the regression analysis. Section 5 concludes.

2. Chronology of the Russian crisis

In this section, we try to identify the events related to the Russian moratorium that are most likely to have affected Swiss bank stocks.

The 69th Annual Report of the Bank for International Settlements (1999, pp. 50–2) provides a well-structured chronology of the Russian crisis: "*Difficulties in controlling public finances, the rising pace of short-term government debt issuance, falling commodity prices and real exchange rate appreciation cast increasing doubt on Russia's debt servicing capabilities in late 1997 and the first half of 1998. As a result, the exchange rate suffered repeated attacks which were met by successive increases in interest rates to 150% by end-May... To buttress rouble stability, which had been a centrepiece of monetary policy for some years, a two-year international financial package of almost $23 billion was offered to Russia in July... However, given strong parliamentary opposition to key revenue-raising measures, implementing IMF's adjustment programme proved difficult… Reserve losses continued and an attempt to lengthen the very short-term maturity of marketable government debt effectively*

[1] Banking Studies Section, Swiss National Bank. The opinions expressed are the author's and do not necessarily reflect those of the Swiss National Bank.

failed, leaving almost $20 billion of short-term rouble debt to be financed before the end of the year. In addition, equity prices reached new lows, domestic interest rates stayed high, and spreads on Russian eurobonds reached 2,000 basis points. Faced with mounting domestic and external financing problems, the Russian authorities announced a radical policy shift in mid-August 1998. The main measures included the widening and subsequent abandonment of the exchange rate band, the suspension of trading in treasury bills combined with a mandated restructuring of government debt, and a 90-day moratorium on the repayment of corporate and bank debt to foreign creditors." In September western banks began discussions with Russia on the debt restructuring, with agreement on the general principles of the restructuring reached in November. In December, however, western creditors rejected the Russian rouble debt deal, and Russia announced the terms of the debt restructuring unilaterally. "*By end-1998, Russia was failing to meet payments on its more than $100 billion foreign currency debt inherited from the Soviet Union.*"

A parallel chronology can be established for international banks' announcements on their exposure, losses and provisioning vis-à-vis Russia. As far as Swiss banks are concerned, UBS announced on 25 August a net exposure of $0.4 billion and trading losses of $0.2 billion. On 26 August Credit Suisse Group (CSG), the parent holding company of Credit Suisse First Boston, acknowledged that Russia's problems would weigh on its profits, after rumours had circulated among traders about its Russian exposure. On 9 September CSG announced an exposure of $2.2 billion and provisioning of $1.1 billion.

By combining the BIS survey with information from Reuters archives, we obtain a list of "key events" related to the Russian financial collapse. Table 1 recapitulates these events with an indication of their expected impact on Swiss bank stocks.

Table 1
Events surrounding the Russian moratorium

Date (1998)	Event	Expected impact	Date (1998)	Event	Expected impact
26.5.	TB interest rates up by 23%	–	27.8.	Worst depreciation of rouble (27%)	–
27.5.	Discount rate tripled to 150%	–	31.8.	Duma rejects Chernomyrdin	?
14.7.	TB interest rates down by 135%	+	9.9.	CSG details exposure and provisions	–
11.8.	TB interest rates up by 74%	–	10.9.	Yeltsin nominates Primakov	?
14.8.	Several Russian banks default on interbank payments	–	17.9.	Talks between banks and Russia on TB	+
17.8.	Moratorium, government abandons rouble floor	–	20.11.	Agreement in principle between Russia and creditor banks	+
20.8.	Rumours about CSG's exposure	–	25.11.	IMF criticises Russia's reforms	–
25.8.	UBS announces net exposure and $0.2 billion loss	?	10.12.	Banks reject debt restructuring	–
26.8.	CSG says Russia's problems with weigh on profits	–			

Source: Reuters.

We expect increases in Russian treasury bill (RTB) interest rates and in the central bank discount rate to have a negative impact on bank stocks, as they reflect the pressures on the rouble exchange rate as well as investors' preoccupations concerning Russia's debt servicing capabilities. The moratorium announcement, if not anticipated by investors, may also depress bank stock returns. Likewise, we expect the failure of several Russian banks to have a negative impact on Swiss bank stocks, as this event made it clear that the Russian banking system was seriously hit by the adverse developments on the RTB and rouble markets. Concerning the negotiations between Russia and its creditor banks, we expect the start of the talks and the announcement of an agreement in principle to have a positive impact on Swiss bank stocks. The banks' rejection of the terms of the debt restructuring, conversely, may have affected bank stocks negatively as it destroyed hopes of a rapid resolution of the crisis. We make no a priori assumption about the impact of Russian political events such as Chernomyrdin's rejection by the Duma and Primakov's nomination by President Yeltsin.

Concerning news on Swiss banks, we expect the rumours about CSG's Russian exposure and the announcement by CSG of its substantial losses in Russia to negatively affect bank stock returns. UBS's announcement of its fairly small Russian losses, conversely, may be considered as good news and we expect this event to affect bank stock returns positively.

3. Database and methodology

3.1 Database

The data sample covers all Swiss-domiciled banks whose equity is traded on the Swiss stock exchange. We distinguish three bank categories: big banks, cantonal banks and foreign or investment banks.

3.2 Event study methodology

We apply event study methodology to determine the magnitude of the stock market reaction to events related to Russia's moratorium. Following Cornell and Shapiro (1986), we use two measures of return.[2] The first measure is the excess return as estimated from the capital asset pricing model (CAPM). The second measure is simply the raw return. The excess return approach has the advantage of relying on a theoretical basis. Its results, however, are sensitive to the choice of risk-free asset and market index. The raw returns approach does not rely on a theoretical foundation, but it has the advantage of avoiding the aforementioned choices.

3.2.1 Excess return approach

We begin the event analysis based on excess returns with an estimation of the CAPM equation:

$$ER_{i,t} = R_{i,t} - (R_{f,t} + \hat{\beta}_i \cdot (R_{m,t} - R_{f,t})) + \varepsilon_{i,t}$$

where $R_{i,t}$ is the daily return on the stock of bank i on day t, $R_{m,t}$ is the daily return on the stock market (Swiss Performance Index)[3] on day t, $R_{f,t}$ is the daily return on the risk-free asset (Confederation debt register claims)[4] on day t, β_i is the beta of the stock of bank I, and $\varepsilon_{i,t}$ is an error term.

Excess returns for each bank or portfolio i are calculated for each event day as the difference between the observed return and the expected return:

$$ER_{i,t} = R_{i,t} - (R_{f,t} + \hat{\beta}_i \cdot (R_{m,t} - R_{f,t}))$$

---

2 See Copeland and Weston (1983), pp. 319–27, for an introduction to event study methodology. A third approach consists in regressing observed returns on an intercept and on a market index in order to obtain "abnormal returns". See Musumeci and Sinkey (1990) and Docking et al. (1997) for an application of the abnormal returns approach to the banking sector.

3 Source: Datastream.

4 Source: Swiss National Bank EASY database.

Standardised excess returns $SER_{i,be}$ or t-values are obtained by dividing the excess return on day i by the standard deviation of excess returns over the estimation period:

$$SER_{i,be} = \frac{ER_{i,be}}{SD(ER_{i,be})}$$

Cumulative returns $CER_{i,be}$ over a particular time interval are computed as

$$CER_{i,be} = \sum_{t=b}^{e} ER_{i,t}$$

for the interval beginning on day $t = b$ and ending on day $t = e$. The cumulative standardised excess return $SCER_{i,be}$ or t-value equals:

$$SCER_{i,be} = \frac{CER_{i,be}}{SD(CER_{i,be})}$$

The standard deviation $SD(CER_{i,be})$ is estimated as:

$$SE(CER_{i,be}) = [T \cdot Var(ER_i) + 2(T-1) \cdot Cov(ER_{i,t}, ER_{i,t-1})]^{0.5}$$

where T represents the number of trading days in the interval $T = e–b+1$. This standard deviation measurement controls for the autocorrelation of returns that may result from event clustering.[5]

3.2.2 Raw returns methodology

Within this approach, we look directly at the raw return $R_{i,t}$ occurring on a given day or over a given time interval. To determine whether the raw return is significant or not, we calculate raw standardised returns as

$$SR_{i,be} = \frac{R_{i,be}}{SD(R_{i,be})}$$

where $SD(R_{i,be})$ is the standard deviation of raw returns over the estimation period.

Cumulative raw returns $CR_{i,be}$ and cumulative standard raw returns $SCR_{i,be}$ are calculated following the procedure described above for excess returns.

3.3 Cross-sectional regression analysis

In the absence of accurate information on each bank's exposure, we can imagine that investors consider that banks belonging to the same category are equally exposed to the Russian crisis. In the Swiss case, investors may consider that the big banks and foreign/investment banks, because of their international orientation, have a larger exposure to Russia than the cantonal banks, whose core business is domestic. Under that assumption, we would expect a sell-off of all big and foreign/investment bank stocks following bad news from Russia.

To test the hypothesis of *category-based discrimination,* we regress each bank's raw or excess returns against dummy variables reflecting the bank's category:

$$R_{i,be} \text{ or } ER_{i,be} = \gamma_1 \cdot BIG_i + \gamma_2 \cdot CAN_i + \gamma_3 \cdot FI_i + \upsilon_{i,be}$$

where BIG_i is unity for big banks and zero otherwise, CAN_i is unity for cantonal banks and zero otherwise, and FI_i is unity for foreign/investment banks and zero otherwise.

The finding of significant differences between the dummy variables would indicate that investors mainly discriminate between banks according to their category.

---

[5] See Ruback (1982), Brunner and Simms (1987) and Madura et al. (1991).

4. Results

4.1 Stock event analysis

In this section, we compute daily and cumulative bank equity returns for each key event inventoried in our chronology of Russia's financial collapse. The purpose of this stock event analysis is to determine whether the Russian financial collapse coincided with significant moves in Swiss bank stock prices and to identify the categories of bank that were most affected.

To save space, we limit our discussion of the results to the stock event analysis based on raw returns. Table 2 presents the raw returns both by event day and cumulated from the start of the tensions on the RTB market. Their standardised values are in parentheses. The results are presented separately for UBS, CSG, a portfolio of cantonal banks and a portfolio of foreign/investment banks (equally weighted portfolios).

Table 2
Event analysis: raw returns

Date	Event	Daily returns				Cumulative returns			
(1998)		CSG	UBS	CAN	FI	CSG	UBS	CAN	FI
26.5.	TB interest rates up by 23%	0.008	0.004	0.003	0.009				
		(0.39)	(0.25)	(0.50)	(0.95)				
27.5.	Discount rate tripled to	–0.020	–0.023	–0.002	–0.005				
	150%	(–1.01)	(–1.49)	(–0.45)	(–0.52)				
14.7.	TB interest rates down by	–0.001	–0.014	0.001	0.020*				
	135%	(–0.07)	(–0.90)	(0.16)	(2.13)				
11.8.	TB interest rates up by	–0.051*	–0.048*	–0.011*	–0.047*	–0.051*	–0.048*	–0.011*	–0.047*
	74%	(–2.66)	(–3.05)	(–2.02)	(–5.15)	(–2.66)	(–3.05)	(–2.02)	(–5.15)
14.8.	Several Russian banks default	0.011	0.032*	–0.002	0.033*	–0.027	–0.008	–0.009	–0.025
	on interbank payments	(0.55)	(2.04)	(–0.40)	(3.56)	(–0.70)	(–0.24)	(–0.84)	(–1.24)
17.8.	Moratorium, government	–0.002	–0.014	0.003	–0.017	–0.028	–0.022	–0.006	–0.042
	abandons rouble floor	(–0.08)	(–0.88)	(0.58)	(–1.91)	(–0.66)	(–0.57)	(–0.50)	(–1.90)
20.8.	Rumours about CSG's	–0.046*	–0.040*	0.000	–0.007	–0.087	–0.062	0.010	–0.038
	exposure	(–2.38)	(–2.56)	(–0.08)	(–0.75)	(–1.62)	(–1.26)	(0.61)	(–1.34)
25.8.	UBS announces net exposure	0.019	0.035*	0.000	0.013	–0.129*	–0.086	–0.014	–0.088*
	and $0.2 billion loss	(0.97)	(2.22)	(0.02)	(1.45)	(–2.03)	(–1.50)	(–0.75)	(–2.65)
26.8.	CSG says Russia's problems	–0.045*	–0.024	–0.007	–0.048*	–0.174*	–0.110	–0.021	–0.136*
	will weigh on profits	(–2.35)	(–1.55)	(–1.25)	(–5.23)	(–2.63)	(–1.84)	(–1.07)	(–3.92)
27.8.	Worst depreciation of	–0.082*	–0.052*	–0.011	–0.061*	–0.257*	–0.161*	–0.031	–0.197*
	rouble (27%)	(–4.28)	(–3.30)	(–1.93)	(–6.63)	(–3.73)	(–2.59)	(–1.54)	(–5.44)
31.8.	Duma rejects	–0.032	–0.027	0.000	–0.025*	–0.287*	–0.223*	–0.039	–0.221*
	Chernomyrdin	(–1.68)	(–1.73)	(–0.04)	(–2.68)	(–3.88)	(–3.32)	(–1.79)	(–5.70)
9.9.	CSG details exposure and	–0.131*	–0.045*	–0.001	0.004	–0.445*	–0.194*	–0.037	–0.238*
	provisions	(–6.80)	(–2.89)	(–0.21)	(0.46)	(–4.97)	(–2.38)	(–1.40)	(–5.06)
10.9.	Yeltsin nominates	–0.066*	–0.084*	–0.011*	–0.048*	–0.511*	–0.278*	–0.048	–0.286*
	Primakov	(–3.42)	(–5.37)	(–1.97)	(–5.21)	(–5.58)	(–3.34)	(–1.77)	(–5.94)
17.9.	Talks between banks and	–0.108*	–0.068*	–0.001	–0.014	–0.562*	–0.324*	–0.049	–0.259*
	Russia on TB	(–5.58)	(–4.32)	(–0.21)	(–1.51)	(–5.56)	(–3.53)	(–1.62)	(–4.86)
20.11.	Agreement in principle	0.050*	0.041*	–0.002	0.035*	–0.331*	–0.262	–0.056	–0.129
	between Russia and banks	(2.60)	(2.62)	(–0.35)	(3.82)	(–2.02)	(–1.75)	(–1.15)	(–1.49)
25.11.	IMF criticises Russia's	–0.029	–0.022	–0.002	–0.005	–0.279	–0.258	–0.051	–0.117
	reforms	(–1.49)	(–1.41)	(–0.33)	(–0.50)	(–1.66)	(–1.69)	(–1.02)	(–1.32)
10.12.	Banks reject debt	–0.070*	–0.013	0.000	0.000	–0.443*	–0.324*	–0.062	–0.133
	restructuring	(–3.61)	(0.33)	(–0.04)	(–1.36)	(–2.47)	(–1.99)	(–1.16)	(–1.41)

The standardised values or t-values are in parentheses. * significant at the 5% level.

Concerning the commencement of the crisis, our results indicate that early increases in RTB rates and the tripling of the central bank discount rate in May 1998 did not significantly affect Swiss bank stock prices. The 74% rise in RTB rates in August, however, coincided with significant negative returns for all Swiss bank categories.

The default of several major Russian banks on the interbank market and the announcement of the moratorium had no significant impact on Swiss bank stocks. A possible interpretation for this absence of reaction is that investors anticipated the moratorium and the disruption of the interbank market, given the tensions observed on the RTB and rouble markets. The 17% depreciation of the rouble in late August coincided with significant negative returns for the two big Swiss banks.

Surprisingly, the start of the discussions between Russia and its creditor banks coincided with significant negative returns for the two big banks. A possible explanation for this reaction could be that investors interpreted the announcement of the negotiations as a confirmation of the gravity of the crisis. The announcement of an agreement in principle between Russia and its creditors in November coincided with significant positive returns for the two big banks. Conversely, CSG shares were affected negatively by western banks' rejection of the debt restructuring and by Russia's unilateral announcement of the restructuring terms in December.

As far as political events are concerned, Chernomyrdin's rejection by the Duma did not affect Swiss bank stocks, while Primakov's nomination by President Yeltsin coincided with significant negative returns for all Swiss bank categories. Investors' reaction may be explained by Primakov's intention to return to a planned economy.

Proceeding to bank-specific news, our results indicate that rumours concerning CSG's exposure to Russia were accompanied by significant negative returns on the two big banks' shares. UBS's announcement of its quite moderate exposure was followed by a significant positive return on its shares. Conversely, CSG's first announcement that Russia's problems would weigh on its profits coincided with a significant negative return on the bank's stock. CSG's release of details on its Russian exposure and provisioning was followed by a very large negative return on the bank's own shares, while UBS also experienced a significant, although smaller, negative return.

A cross-category comparison of the results of the stock event analysis indicates that CSG shares were the most affected by the Russian financial collapse. UBS and foreign/investment bank stock returns were affected less often and less significantly than CSG shares. Cantonal bank shares reacted only on two occasions, and by little. This differentiation in market reaction seems at first sight reasonable, given that CSG experienced more substantial losses than UBS in Russia and that cantonal banks, because of their domestic orientation, are unlikely to have a significant exposure to Russia.

The last four columns of Table 2 present raw returns cumulated as from 11 August. Cumulated raw returns reached their minimum at –0.576 for CSG (significant at the 1% level), –0.440 for UBS (significant at the 1% level), –0.321 for the foreign/investment bank portfolio (significant at the 1% level) and 0.066 (significant at the 5% level) for the cantonal bank portfolio. For three bank categories, the minimum coincides with the start of the talks between Russia and its creditor banks. The figures obtained for CSG and UBS indicate that the equity value of the two big banks measured at market prices was nearly halved during the most turbulent phase of the Russian crisis. This seems quite impressive when compared to the losses announced by the two big banks for their Russian operations, as they represented "only" 7% of CSG's equity and 1% of UBS's equity.

The findings of our stock event analysis can be summarised as follows. First, Swiss bank stocks did not react to the announcement of the Russian moratorium itself, but were negatively affected by the tensions in the RTB and rouble markets. Here, a plausible interpretation is that the moratorium came as no surprise to investors, given the adverse financial and economic context. Secondly, the Russian financial collapse affected CSG shares more than those of UBS and the cantonal banks; a priori, this result seems consistent with the respective losses announced by the two big banks and with the low international profile of the cantonal banks. Thirdly, the cumulated negative stock returns observed for the two big banks are much larger than the announced losses vis-à-vis Russia. Here a possible explanation is that investors, in a context of financial instability, feared that large banks could also suffer considerable losses on their exposures to other emerging market countries.

4.2 Results of the cross sectional analysis

In this subsection we present the results of the cross-sectional regression analysis. The model is estimated for each event characterised by a significant raw return or excess return. Given the heteroscedasticity in raw returns and excess returns, the t-statistics of the estimated coefficients may be biased. To cope with this problem, we use the White (1980) heteroscedasticity-consistent covariance matrix estimator, which provides correct t-statistics for the coefficient estimates in the presence of heteroscedasticity of unknown form.

Table 3 presents the model estimates based on raw returns. The big bank dummy is negative and significant for all events, except for the announcement of the agreement in principle, where it is positive and significant. The cantonal bank dummy is negative and significant for two events only. The foreign/investment bank dummy is significant and negative for seven events, and positive and significant for the announcement of the agreement in principle. Differences between the bank category dummies are highly significant for the great majority of events.

Table 3
Model estimates based on raw returns

Date (1998)	Event	BIG	CAN	FI	R2
11.8.	TB interest rates up by 74%	–0.05*	–0.02	–0.04*	0.16
		(0.01)	(0.06)	(0.00)	
20.8.	Rumours about CSG's exposure	–0.04*	0.00	–0.01	0.49
		(0.00)	(0.55)	(0.25)	
25.8.	UBS announces net exposure and	0.03*	0.00	0.02*	0.36
	$0.2 billion loss	(0.01)	(0.94)	(0.01)	
26.8.	CSG announces Russia's problems	–0.03*	–0.01*	–0.03*	0.06
	will weigh on profits	(0.04)	(0.05)	(0.01)	
27.8.	Worst depreciation of rouble (27%)	–0.07*	–0.02*	–0.06*	0.33
		(0.01)	(0.05)	(0.00)	
31.8.	Duma rejects Chernomyrdin	–0.03*	0.00	–0.03*	0.36
		(0.02)	(0.55)	(0.00)	
9.9.	CSG details exposure and provisions	–0.09*	0.00	0.01	0.63
		(0.00)	(0.63)	(0.30)	
10.9.	Yeltsin nominates Primakov	–0.08*	–0.02	–0.04*	0.30
		(0.00)	(0.06)	(0.01)	
17.9.	Talks between banks and	–0.09*	0.00	–0.02*	0.79
	Russia on TB	(0.00)	(0.44)	(0.03)	
20.11.	Agreement in principle between	0.05*	0.00	0.02*	0.50
	Russia and creditor banks	(0.00)	(0.72)	(0.01)	
10.12.	Banks reject debt restructuring	–0.04*	0.00	0.00	0.34
		(0.01)	(0.96)	(0.93)	

In parentheses: p-values derived from a t-Student test based on White's coefficient covariance matrix. * significant at the 5% level.

Table 4 presents the model estimates based on excess returns. The big bank dummy is negative and significant for four events, and positive and significant for the announcement of the agreement in principle. The cantonal bank dummy is never significant. The foreign/investment bank dummy is significant and negative for three events, and positive and significant for one event. Differences between the bank category dummies are highly significant for the great majority of events.

Table 4
Model estimates based on excess returns

Date (1998)	Event	BIG	CAN	FI	R2
11.8.	TB interest rates up by 74%	–0.01	–0.01	–0.02*	–0.09
		(0.54)	(0.11)	(0.05)	
17.8.	Moratorium	0.00	0.00	–0.01	0.01
		(0.79)	(0.63)	(0.18)	
20.8.	Rumours about CSG's exposure	–0.03*	0.00	0.00	0.36
		(0.00)	(0.86)	(0.93)	
25.8.	UBS announces net exposure and	0.01	0.00	0.01	0.03
	$0.2 billion loss	(0.49)	(0.54)	(0.21)	
26.8.	CSG announces Russia woes	–0.01	–0.01	–0.02*	–0.05
	weigh on profits	(0.51)	(0.06)	(0.02)	
27.8.	Worst depreciation of rouble (27%)	–0.01	–0.01	–0.04*	0.26
		(0.47)	(0.06)	(0.00)	
31.8.	Duma rejects Chernomyrdin	–0.01	0.00	–0.02*	0.22
		(0.21)	(0.82)	(0.01)	
9.9.	CSG details exposure and provisions	–0.06*	0.00	0.03*	0.60
		(0.00)	(0.90)	(0.01)	
10.9.	Yeltsin nominates Primakov	–0.03	–0.01	–0.01	–0.07
		(0.07)	(0.11)	(0.15)	
17.9.	Talks between banks and	–0.04*	0.00	0.01	0.67
	Russia on TB	(0.00)	(0.36)	(0.24)	
20.11.	Agreement in principle between	0.02*	0.00	0.01	0.24
	Russia and creditor banks	(0.03)	(0.66)	(0.18)	
10.12.	Banks reject debt restructuring	–0.02	0.00	0.01	0.19
		(0.06)	(0.72)	(0.30)	

In parentheses: p-values derived from a t-Student test based on White's coefficient covariance matrix. *significant at the 5% level.

Overall, the results of the-cross sectional regression analysis provide strong evidence in favour of the hypothesis that in the absence of official information on bank' individual exposures to Russia, investors discriminated mainly according to bank category.

5. Conclusions

In this paper, we have studied the impact of the Russian crisis on Swiss bank stock prices. In a first step, using stock event analysis, we tried to determine the events related to the Russian moratorium that coincided with significant returns on Swiss bank shares. Our results indicate that Swiss bank stocks were negatively affected by the tensions in the RTB and rouble markets, but that they did not react to the Russian debt moratorium itself. Here, a possible interpretation is that the moratorium was not a surprise for investors, given the adverse financial and economic context. In a second step, we regressed each bank's stock against dummy variables reflecting the category of the bank. Our estimates provide strong evidence in favour of the hypothesis that in the absence of official information on banks' individual exposures to Russia, investors discriminated mainly according to bank category.

Bibliography

Bank for International Settlements (1999): *69th Annual Report*, June, pp. 50-2.

Bruner, Robert F and John M Simms Jr. (1987): "The International Debt Crisis and Bank Security Returns in 1982". *Journal of Money Credit and Banking*, Vol. 19, No. 1, pp. 47-55.

Copeland, Thomas E and J Fred Weston (1983): *Financial Theory and Corporate Policy, Second Edition*, by Addison-Wesley Publishing Company, Inc.

Cornell, Bradford and Alan C Shapiro (1986): "The Reaction of Bank Stock Prices to the International Debt Crisis". *Journal of Banking and Finance* 10, pp. 55-73.

Docking, Diane Scott, Mark Hirschey and Elaine Jones (1997): "Information and contagion effects of bank loan-loss reserve announcements". *Journal of Financial Economics* 43, pp. 219-39.

Karafiath, Imre, Ross Mynatt and Kenneth L Smith (1991): "The Brazilian default announcement and the contagion effect hypothesis". *Journal of Banking and Finance* 15, pp. 699-716.

Kaufman, George (1994): "Bank Contagion: a Review of the theory and Evidence". *Journal of Financial Services Research 8(2)*, pp. 123-50.

Madura, Jeff, Anne Marie White and William R McDaniel (1991): "Reaction of British bank share prices to Citicorp's announced $3 billion increase in loan-loss reserves". *Journal of Banking and Finance* 15, pp. 151-63.

Musumeci, James J and Joseph F Sinkey, Jr. (1990): "The International Debt Crisis, Investor Contagion, and Bank Security Returns in 1987: The Brazilian Experience". *Journal of Money, Credit, and Banking*, pp. 209-20.

Wall, Larry D and David R Peterson (1990): "The effect of Continental Illinois' failure on the financial performance of other banks". *Journal of Monetary Economics* 26, pp. 77-99.

International financial crises and flexible exchange rates: some policy lessons from Canada

John Murray, Mark Zelmer and Zahir Antia[1]

"In other words, for cyclical as well as for more fundamental reasons, the prospects are good for a stronger Canadian currency." [2]

1. Introduction

The near-term prospects for the Canadian economy and the Canadian dollar looked very promising in early 1997. Canada's current account balance had swung into surplus for the first time in 11 years; the federal government deficit had finally been eliminated; public sector debt was now on a clear downward track; world commodity prices had recovered from their 1992–93 lows; and inflation had remained steady at 1 to 2% for more than five years.

While the Governor's exchange rate forecast may seem optimistic in retrospect, this positive outlook was shared by many other observers. Canadian interest rates had fallen below comparable US rates across the yield curve, suggesting that most investors believed the Canadian dollar would soon appreciate and continue to strengthen for several years to come. The only question was how high it would go. Some market analysts were concerned that the dollar might strengthen too much, undermining Canada's new-found competitiveness and throwing the economy back into recession.

> *"Can Canada compete with a higher currency?... C$ bulls may soon be pointing to 80 cents US as a fair evaluation of C$ fundamentals... [However] without an extraordinary response from Canadian consumers growth in our borderline economy could easily come to a standstill or worse."*[3]

While there was widespread agreement among analysts and most forecasting groups that the Canadian dollar would soon appreciate, few of them shared Buchanan's and Rubin's concerns about the "borderline" growth prospects in Canada (or the world economy more generally). Both the IMF and the OECD predicted that growth in Canada would be higher than in any other G7 country, reaching 3.5% in 1997 and 3.3% in 1998. World output was expected to grow by more than 4% a year, and world trade was expected to increase by more than 9% – continuing a trend that had started in 1994.

In the event, none of these optimistic predictions came true. Although the Canadian economy did post respectable growth rates in 1997 and 1998, they were not the highest in the G7.[4] (That honor belonged to the United States, which grew by 3.9% in both years.) The performance of the Canadian dollar was even more disappointing. It fell from an average level of US 74 cents in the first quarter of 1997 to a

---

[1] The views expressed in this paper are those of the authors. No responsibility for them should be attributed to the Bank of Canada. John Murray works in the International Department of the Bank of Canada, while Mark Zelmer and Zahir Antia work in the Financial Markets Department. The authors would like to thank Robert Amano, David Laidler, James Powell and Lawrence Schembri for their helpful comments. They are also grateful for the invaluable technical assistance provided by Jason Daw and Francine Rioux.

[2] Excerpted from "Flexible Exchange Rates in a World of Low Inflation". Remarks by Gordon Thiessen, Governor of the Bank of Canada, to the FOREX '97 Conference in Toronto, 30 May 1997.

[3] See Rubin and Buchanan (1996).

[4] Real economic growth in Canada was 3.3% in 1997 and 2.8% in 1998.

record low of US 63.1 cents in the third quarter of 1998 – roughly 15% below its starting point (see Graph 1).[5]

Although the reasons for the weakness of the Canadian dollar are easy to identify ex post, few observers were able to anticipate them ex ante. Indeed, a brief review of the reports and newsletters that were published immediately before the Asian crisis failed to uncover any analyst who correctly forecast the traumatic events that were about to unfold. The IMF, the OECD and the Bank of Canada can perhaps be forgiven, therefore, for not being more perspicacious than the rest of the economics profession.

Graph 1: Canadian dollar against the US dollar

Weekly (average of Wednesdays)

Canada, of course, was not the only industrial country to be affected by the Asian crisis and the resulting collapse in world commodity prices. Other countries, such as Australia and New Zealand, which had more extensive trade links with Asia and were more dependent on commodity exports, saw their currencies fall much further. These dramatic depreciations did not provide much comfort to analysts and investors who had counted on a stronger Canadian dollar, however; nor to the Canadian public, who awoke each day to find their currency at a new historical low. Had it not been for the positive forecasts that had preceded this sudden downturn, and the proximity of the surging US economy, the disappointment might not have been so great. There was a widespread sense during much of this period that the Canadian dollar had fallen much further than fundamentals alone could justify. Although some of this angst disappeared with the subsequent recovery of the dollar, the experience of the last three years has raised new concerns about the destabilizing effects of exchange market speculation and the practicality of a flexible exchange rate. Critics of the existing system have called for a new, more rigid currency arrangement with the United States, including perhaps the introduction of a common currency.

The purpose of the present paper is to examine the behavior of the Canadian dollar over the last three years and to determine the extent to which it has been oversold or pushed below its "fair" market

[5] Of course, were it not for the "disappointing" performance of the dollar, Canada's real growth in 1997 and 1998 would have been much lower.

value. The principal tool for our analysis is a simple exchange rate equation that was first developed at the Bank of Canada in the early 1990s. Extensive testing with the equation during the past nine years has shown that it is able to explain most of the broad movements in the dollar over the post-Bretton Woods period.

Three major conclusions can be drawn from the evidence that is presented below. First, any difference between the actual and predicted values of the Canadian dollar over the past three years has been small and generally short-lived. Overshooting has not been a major problem. Second, the dollar's current value is very close to the fitted values predicted by our simple exchange rate equation and is not significantly undervalued. Most of its recent weakness can be explained by two or three critical variables. Third, periods of market turbulence and increased exchange rate volatility, like the ones associated with the Asian and Russian crises, are typically dominated by fundamentalists rather than destabilizing speculators. Efforts by the Bank of Canada to resist these movements through exchange market intervention or higher interest rates are therefore likely to reduce market efficiency. Tactical manoeuvres to support the exchange rate and calm market expectations should be used sparingly, where there is clear evidence of market failure and the remedial interest rate increases can be quickly reversed.

The rest of the paper is organized as follows. Section 2 describes the basic exchange rate equation that is used in our analysis and presents the results of a number of simulations designed to measure the extent to which the dollar has been undervalued. Section 3 extends the analysis by adding two new variables to the exchange rate equation – differences in Canadian-US productivity and the level of public debt – to see if they improve its explanatory power. The role of speculative bubbles and destabilizing currency traders is investigated in Section 4 with the aid of a regime-switching model. The final section of the paper provides a summary of the main results and some suggestions for future work.

2. The basic exchange rate equation

The Bank of Canada's exchange rate equation is based on a simple error-correction model that was first developed by Robert Amano and Simon van Norden in 1991. The dependent variable is the real Canadian-US exchange rate, and its equilibrium value is determined by two independent variables: the energy terms of trade, and the commodity terms of trade (ex-energy). Short-run dynamics are captured by changes in the Canadian-US interest rate differential.

The equation can be written as follows:

(1) $$\Delta\ln(rfx) = \alpha(\ln(rfx)_{t-1} - \beta_0 - \beta_c\, comtot_{t-1} - \beta_e\, enetot_{t-1}) + \gamma intdif_{t-1} + \varepsilon_t$$

where *rfx* = real Canadian-US exchange rate, *comtot* = non-energy commodity terms of trade, *enetot* = energy terms of trade and *intdif* = Canadian-US interest rate differential.

The dependent variable, *rfx*, is simply the nominal Canadian-US exchange rate deflated by either the CPI or the GDP price index. The choice of deflator makes little difference to the resulting time series since the CPI and GDP price indices move in a very similar manner over the sample periods relevant for our study. The two independent variables, *enetot* and *comtot*, are obtained by dividing the US dollar price of energy and non-energy commodities by the US GDP deflator. The effects of Canadian and US monetary policies on the real exchange rate are proxied by *intdif*, which is simply the difference between Canadian and US short-term interest rates.[6]

[6] The specification described above differs from the original Amano-van Norden equation in three respects. First, the energy and commodity terms of trade are deflated by the GDP price index rather than the price of US manufactured goods. Second, oil prices are used as a proxy for all energy prices. Third, the interest rate differential is just the spread between Canadian and US short-term interest rates rather than the difference between long-term and short-term interest rates in the two countries. These changes have no significant effect on the performance of the equation and were introduced simply to reduce the number of data series that were required to use it.

$$intdif = (i_{st}^{ca} - i_{st}^{us})$$

While equation (1) contains many of the variables that one would expect to find in a Canadian-US exchange rate relationship, and has performed surprisingly well over the past nine years, it is important to note that Amano and van Norden only arrived at this simple specification after testing over a much larger set of explanatory variables. The fact that the relationship has remained stable through time and has retained much of its explanatory power is remarkable, particularly for an exchange rate equation, and is testament to the important influence that *comtot*, *enetot* and *entdif* exert on the Canadian dollar.[7]

2.1 Regression results

Representative results for the basic exchange rate equation estimated over four different sample periods are shown in Table 1. As the reader can see, most of the parameters are statistically significant and have their expected signs. Since the dependent variable is defined in a way that associates downward movements in the exchange rate with appreciations (and upward movements with depreciations), the results suggest that increases in *comtot* and *intdif* cause the exchange rate to strengthen, while increases in *enetot* cause it to weaken. Although the latter may seem counter-intuitive, and was not expected when Amano and van Norden first ran their regressions, it has proven to be a remarkably robust result. Indeed, it was only when energy and non-energy commodity prices were separated into two variables, and allowed to affect *rfx* in different ways, that the equation was able to work. Earlier results, based on a single commodity price variable which combined the two effects, proved disappointing.

The unexpected result on the energy price term can be explained by noting that Canada is only a marginal net exporter of energy products, but has other industries which are very energy-intensive. As a consequence, the benefits realized from larger energy exports when the price of energy increases are more than offset by the additional costs borne by other Canadian industries.[8] Higher energy prices, therefore, cause the real exchange rate to depreciate.

Table 1
Standard exchange rate equation

Variable	1973Q1–1986Q1	1973Q1–1991Q3	1973Q1–1996Q1	1973Q1–1998Q4
Speed of adjustment	–0.198	–0.167	–0.141	–0.125
	(–3.251)	(–3.917)	(–4.149)	(–3.752)
Constant	2.419	1.807	2.728	3.040
	(4.585)	(5.306)	(7.566)	(7.672)
comtot	–0.454	–0.368	–0.524	–0.580
	(–4.794)	(–5.713)	(–6.558)	(–6.328)
enetot	0.059	0.119	0.070	0.057
	(1.442)	(2.916)	(1.769)	(1.298)
intdif	–0.540	–0.519	–0.604	–0.576
	(–2.442)	(–3.105)	(–3.682)	(–4.040)
R2	0.218	0.227	0.204	0.194
Durbin-Watson	1.197	1.159	1.265	1.311

Note: t-statistics in parentheses.

7 The unit root and cointegration tests that were used to check the original specification are described in Appendix 1.

8 Macklem (1993) has constructed a three-sector general equilibrium model of the Canadian economy which generates results very similar to those described above.

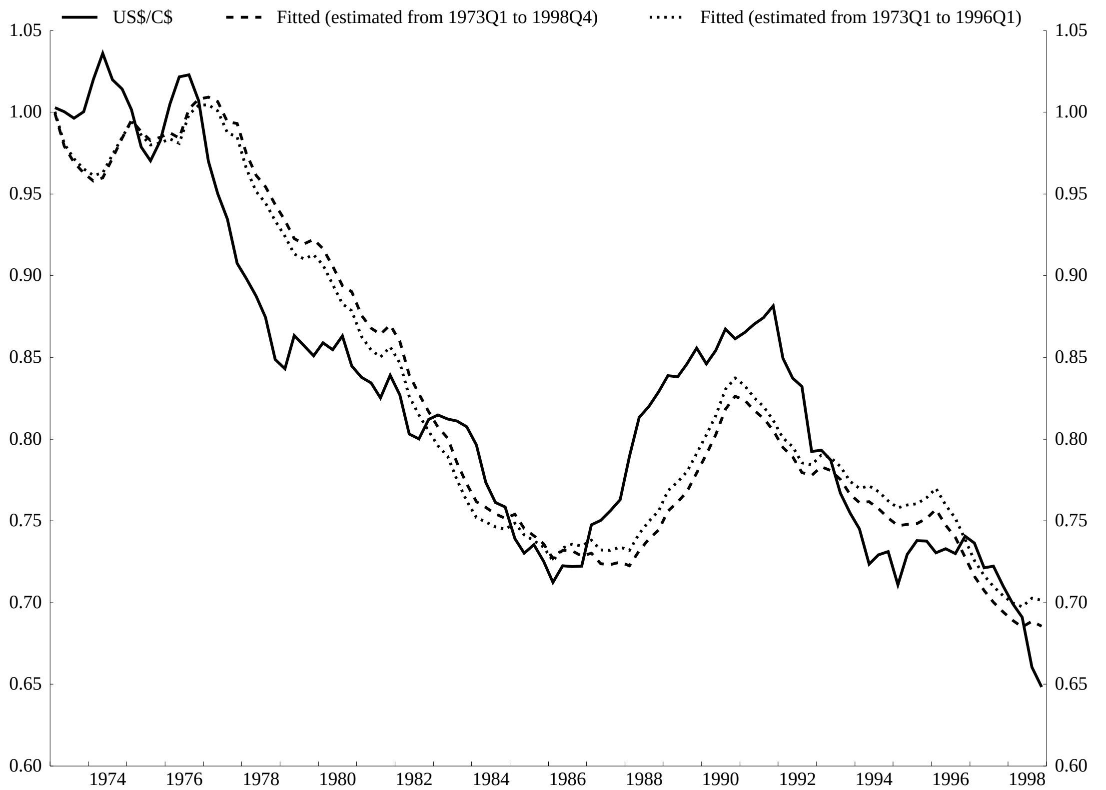
The only other feature of the regression results that might seem surprising is the long implied adjustment lag associated with changes in commodity prices. While long lags are not unusual in simple reduced-form models of this kind, the mean adjustment lag in equation (1) is approximately four quarters. One might have expected the response time to be much shorter for an asset price variable such as *rfx*. The more gradual reaction that is observed in equation (1) suggests that agents wait to see if commodity price changes are permanent before factoring them into the exchange rate completely.

Aside from these two anomalies, the performance of the basic equation is quite impressive. It is able to explain roughly 20% of the quarterly variation in the real exchange rate; the relationship is remarkably robust; and its parameters are (for the most part) sensibly signed and significant.[9] Tests of the model's ex ante predictive power also indicate that it is able to beat a random walk (see the original Amano and van Norden (1993) paper). While the latter may seem like a rather modest benchmark, few exchange rate equations are able to make this claim.

2.2 Simulations

Two dynamic simulations are shown in Graph 2, using parameter estimates drawn from the periods 1973Q1–1996Q1 and 1973Q1–1998Q4. In order to facilitate comparisons between the actual and predicted values of the exchange rate, *rfx* was first converted into a nominal exchange rate by adjusting the real series for changes in the Canadian and US GDP price deflators.

Graph 2: Dynamic simulation - basic model



9 Some variability in the parameter estimates is observed over the 1973–91 sample compared to other periods. This may be due to the sizable overshooting of the exchange rate towards the end of the 1980s. In any event, none of the differences is statically significant. Parameter stability tests that were conducted as part of an earlier exercise indicated that the estimates never exceeded their 5% confidence bands.

The correspondence between the simulated values of the nominal exchange rate and its actual value is very close. Most of the broad movements in the exchange rate are captured by the three explanatory variables. Sizeable deviations do occur on occasion, but they typically disappear after a short period of time. The 1987–90 episode is an example of this. While 1998 may provide another example of speculative overshooting, the deviations that were recorded over this "crisis" period appear to be relatively modest compared to earlier episodes. Moreover, the actual exchange rate has now returned to a level that is very close to what the equation would predict. In other words, very little of an exceptional or potentially troubling nature was observed during this period of international turbulence.

Table 2 provides a decomposition of one of the simulations shown in Graph 2, and indicates the relative contribution of each variable to changes in the actual Canadian-US exchange rate.

Table 2
Relative importance of the explanatory variables 1973Q1–1998Q4

Variable	Percentage share
comtot	56.20
enetot	1.85
intdif	–6.52
Inflation	23.00
Lags	11.51
Other*	13.76
Total	100.00

* Includes error term.

Over the 1973Q1–1998Q4 period, the nominal bilateral exchange rate depreciated by roughly 44 cents (Canadian). Of this, more than 56% was the result of a trend decline in the relative price of non-energy commodities; 23% was caused by higher inflation in Canada than in the United States (purchasing power parity); 2% came from higher energy prices; and 25% was related to other unidentified factors (including the lagged adjustment term and the residual error). Short-term interest rate differentials provided some offset to the depreciation and raised the value of the dollar by roughly 7%.

3. An extended equation

The results reported in the previous section suggest that most of the movements in the exchange rate have been driven by two or three fundamental variables, and that it would be possible to predict the general direction of the exchange rate, if not its exact level, provided one had prior knowledge of these forcing variables. Nevertheless, independent of which sample period is used to estimate the equation, it tends to overpredict the actual value of the exchange rate over most of the 1990s. Is this evidence of overshooting or is there a chance that other explanatory variables might be uncovered that could help explain these discrepancies?

Amano and van Norden (1993) ended their estimations in 1992Q2. While the regressions reported above in Table 1 extend their results to 1998Q4, no new variables have been added to the original equation. The same specification has simply been applied to more data. Although the new results are essentially unchanged vis-à-vis those of Amano and van Norden, the longer sample that is now available might allow us to uncover additional variables that could help explain the "undervalued" dollar over the 1992–98 period.

3.1 Canadian-US differences in productivity and government debt

Several new variables have been examined as part of an effort to find a new and improved exchange rate equation for the Canadian dollar. A complete list of the variables that have been tested is contained in a recent paper written by two colleagues, David Tessier and Ramdane Djoudad, who have conducted a more exhaustive study of this issue.[10]

Rather than reproduce all of the results of Tessier and Djoudad, we have decided to focus our attention on two variables: the difference in Canadian and US labor force productivity, and the difference in Canadian and US general government debt. These variables are of particular interest owing to the public attention that they have attracted in recent months. Moreover, the results that we obtain are broadly similar to those reported by Tessier and Djoudad using a number of other specifications.

(i) Productivity

Sagging productivity has been the focus of a lively public debate in Canada since late last year, when the OECD published a report suggesting that the level of labor productivity in Canada's manufacturing sector was well below that in the United States, and was also growing at a much slower rate. Although the data on which these results were based have now been revised, and the productivity growth puzzle seems to have largely disappeared, the debate continues. As a result, there is considerable interest in seeing if any evidence of a productivity slowdown can be detected in the exchange rate equation. Since Canada is not a large enough producer to materially affect the world price of most commodities, and is unlikely to suffer from "immiserizing growth", one would expect lower productivity growth to cause the Canadian dollar to depreciate. (It is important to note, however, that the exchange rate effects of a (relative) decline in productivity are in theory ambiguous.)

(ii) Government debt

The high level of government debt in Canada relative to that in the United States has also been a source of concern in recent years. As with slow productivity growth, one would also expect it to lead to an exchange rate depreciation, since countries must eventually pay for any excess absorption with higher net exports. (This assumes that the counterpart of higher domestic debt is higher foreign indebtedness.) In the short run, however, the net effect of higher government debt on the exchange rate could be ambiguous. The positive demand shock generated by higher government spending and reduced taxes might be expected to put upward pressure on the exchange rate, in part through higher interest rates.[11] On the other hand, if the outstanding debt were to approach levels that raised concerns about the government's ability to service it, the positive Keynesian effect described above could easily be outweighed by risk considerations, causing domestic interest rates to rise and the exchange rate to depreciate. Whether the statistical techniques employed below will be able to disentangle these conflicting effects, and the sudden changes in market sentiment that might occur once certain debt thresholds are breached, is unclear.

3.2 Regression results

Preliminary tests which were run on the new variables prior to estimating the extended model suggest that any results one might obtain should be treated with caution, since it was impossible to identify a stable cointegrating relationship between the new variables and the exchange rate.[12] Nevertheless, it is interesting to see how the results compare with those of the original specification reported in Table 1.

---

10 See Tessier and Djoudad (1999). Some of the variables that Tessier and Djoudad considered were (1) differences in Canadian-US unemployment rates, (2) differences in Canadian-US productivity, (3) differences in Canadian-US government spending, (4) differences in Canadian-US foreign indebtedness, and (5) differences in the levels of Canadian and US government debt.

11 Although Canadian-US interest rate differentials are entered as a separate variable, the stimulative short-run effects of increased government spending and lower taxes could still lead to an appreciation of the exchange rate through other channels.

12 Unit root and cointegration tests for the extended model are reported in Appendix 2.

The three new equations that were estimated can be written as follows:

(2) $\Delta\ln(rfx) = \alpha(\ln(rfx)_{t-1} - \beta_0 - \beta_c\, comtot_{t-1} - \beta_e\, enetot_{t-1} - \beta_d\, debtdif_{t-1}) + \gamma\, intdif_{t-1} + \varepsilon_t$

where *debtdif* = Canadian government debt to GDP ratio less US government debt to GDP ratio;

(3) $\Delta\ln(rfx) = \alpha(\ln(rfx)_{t-1} - \beta_0 - \beta_c\, comtot_{t-1} - \beta_e\, enetot_{t-1} - \beta_p\, proddif_{t-1}) + \gamma\, intdif_{t-1} + \varepsilon_t$

where *proddif* = Canadian-US labor productivity differential; and

(4) $\Delta\ln(rfx) = \alpha(\ln(rfx)_{t-1} - \beta_0 - \beta_c\, comtot_{t-1} - \beta_e\, enetot_{t-1} - \beta_d\, debtdif_{t-1}) - \beta_p\, proddif_{t-1} + \gamma\, intdif_{t-1} + \varepsilon_t$

Table 3
Standard exchange rate equation with government debt

Variable	1973Q1–1986Q1	1973Q1–1991Q3	1973Q–1996Q1	1973Q1–1997Q4
Speed of adjustment	–0.300	–0147	–0.162	–0.156
	(–3.278)	(–3.295)	(–4.156)	(–4.173)
Constant	1.781	2.541	2.089	2.235
	(3.983)	(3.719)	(3.472)	(3.631)
comtot	–0.297	–0.515	–0.402	–0.430
	(–3.251)	(–3.710)	(–3.448)	(–3.588)
enetot	0.032	0.1033	0.090	0.083
	(1.031)	(2.182)	(2.145)	(1.987)
intdif	–0.465	–0.476	–0.627	–0.566
	(–2.035)	(–2.771)	(–3.735)	(–3.981)
debtdif	0.804	–0.587	0.302	0.180
	(2.014)	(–1.290)	(1.159)	(0.706)
R2	0.238	0.243	0.205	0.207
Durbin-Watson	1.148	1.230	1.238	1.311

Note: t-statistics in parentheses.

Table 4
Exchange rate equation with productivity

Variable	1973Q1–1986Q1	1973Q1–1991Q3	1973Q1–1996Q1	1973Q1–1997Q4
Speed of adjustment	–0.281	–2.07	–0.144	–0.147
	(–5.017)	(–5.347)	(–4.258)	(–4.468)
Constant	2.400	2.740	3.478	3.307
	(7.258)	(8.521)	(5.859)	(6.306)
comtot	–0.477	–0.529	–0.653	–0.622
	(–7.787)	(–8.367)	(–5.535)	(5.905)
enetot	0.106	0.080	0.037	0.043
	(3.559)	(2.932)	(0.936)	(1.146)
intdif	–0.622	–0.411	–0.565	–0.645
	(–3.234)	(–2.715)	(–3.392)	(–4.474)
proddif	1.059	1.015	0.618	0.414
	(3.994)	(4.044)	(1.812)	(1.790)
R2	0.429	0.415	0.230	0.234
Durbin-Watson	1.637	1.563	1.326	1.369

Note: t-statistics in parentheses.

The first thing to note from the results reported in Table 3 for the government debt variable is that, while *debtdif* often enters equation (2) with the expected positive sign (i.e. higher debt leads to a weaker exchange rate), it is seldom significant. Indeed, the only period in which it has a t-statistic greater than 2.0 is 1973Q1 to 1986Q1, when Canada's debt-to-GDP ratio was growing but still much lower than that of the United States. The productivity variable, in contrast, is significant at the 10% level in all four sample periods (see Table 4), but always has the wrong sign (i.e. higher relative productivity leads to a weaker exchange rate). When both variables are entered into the equation simultaneously, they become highly significant over the last two sample periods, but *proddif* still has the wrong sign. Interestingly, none of the other variables in the original equation is affected by the addition of the new variables, though their t-statistics are sometimes slightly higher (see Table 5).

Table 5
Exchange rate equation with government debt and productivity

Variable	1973Q1–1986Q1	1973Q1–1991Q3	1973Q1–1996Q1	1973Q1–1997Q4
Speed of adjustment	–0.262	–0.216	–0.211	–0.199
	(–3.25)1	(–5.100)	(–5.374)	(–5.178)
Constant	2.568	2.580	2.162	2.206
	(3.879)	(6.222)	(4.917)	(4.801)
comtot	–0.520	–0.491	–0.401	–0.412
	(–3.277)	(–6.075)	(–4.781)	(–4.666)
enetot	0.118	0.084	0.081	0.801
	(2.365)	(3.055)	(2.701)	(2.552)
intdif	–0.844	–0.417	–0.557	–0.685
	(–3.141)	(–2.732)	(–3.484)	(–4.847)
debtdif	–0.205	0.137	0.782	0.637
	(–0.309)	(0.560)	(3.640)	(2.932)
proddif	1.183	1.031	0.898	0.605
	(2.363)	(4.217)	(3.564)	(3.205)
R2	0.418	0.409	0.296	0.273
Durbin-Watson	1.672	1.559	1.366	1.367

Note: t-statistics in parentheses.

3.3 Simulations

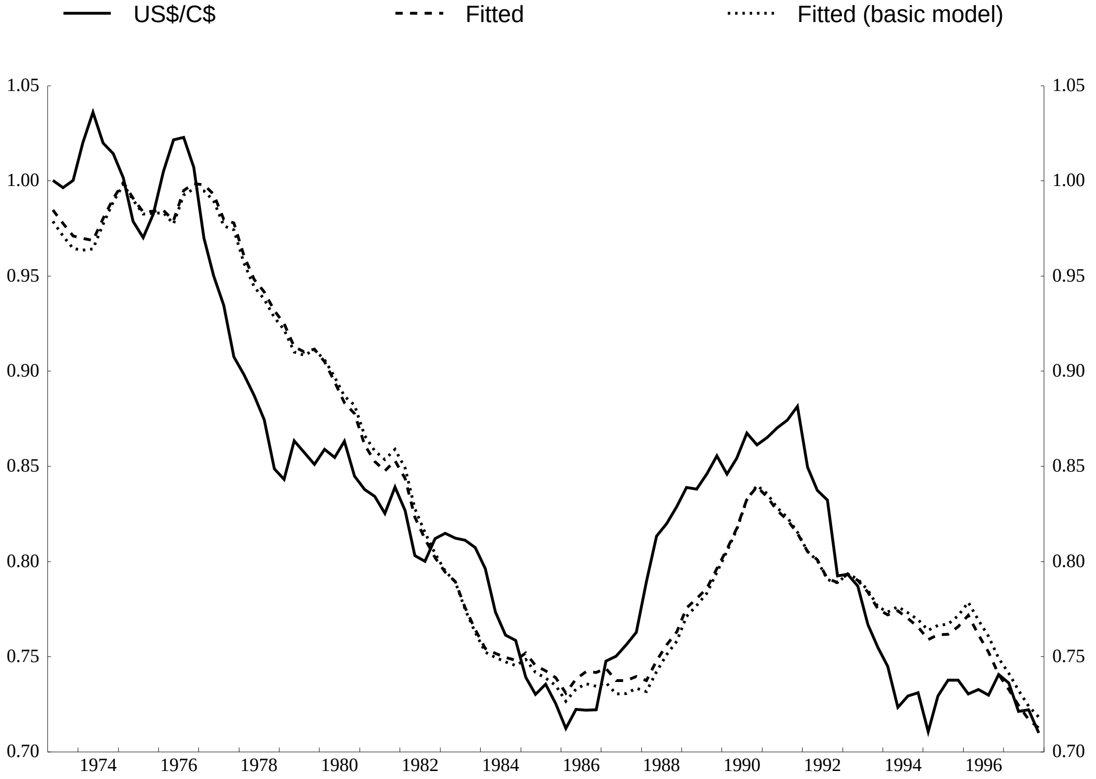
Graphs 3, 4 and 5 compare the actual value of the nominal Canadian-US exchange rate with the simulated value from the original equation and those of equations (2), (3) and (4). Unfortunately, the simulations have to end in 1997Q4 since the debt and productivity variables that we use are not available for 1998 or 1999. While the extra variables seem to improve the explanatory power of the equation, the overshooting that was noted in earlier simulations over much of the 1990s is still evident.

Differences in national debt and labor productivity do not seem to provide the missing link that we were looking for. Neither do they represent a very reliable addition to the basic model that we first examined. Perhaps the overshooting that we have observed has been driven by other forces, such as the destabilizing behavior of noise traders and speculators who, popular wisdom suggests, regularly cause exchange rates to become disconnected from market fundamentals.

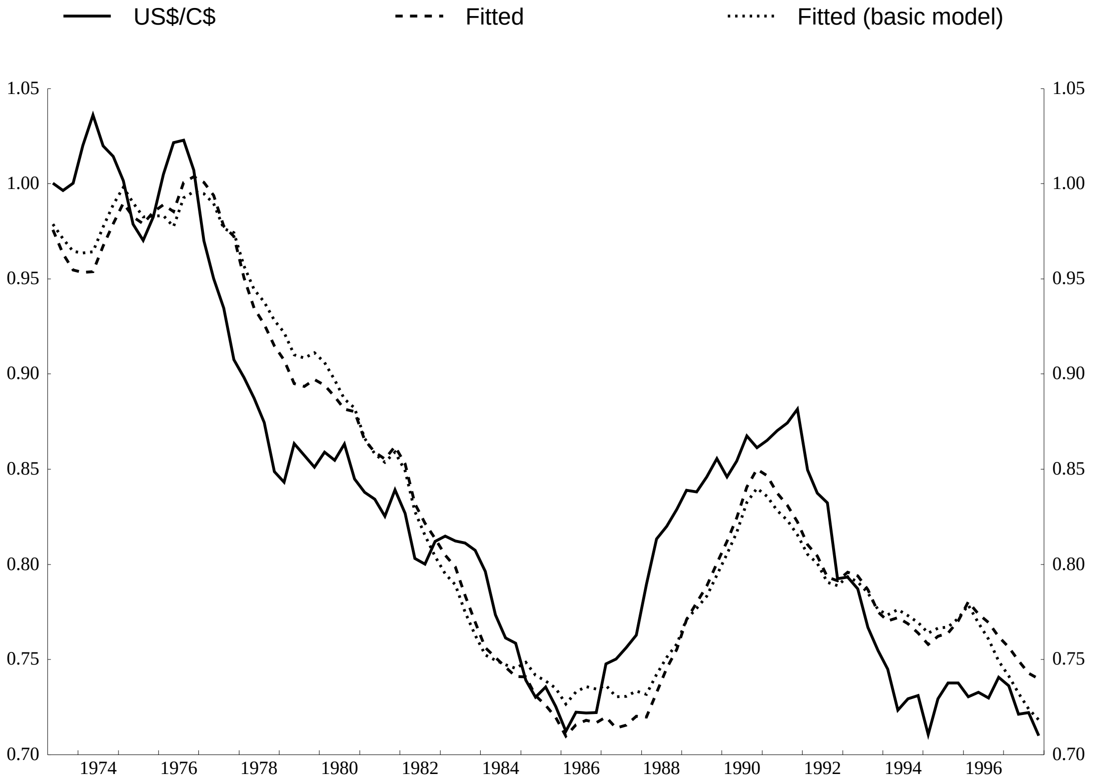
4. Excess volatility and speculative bubbles

Chartists and noise traders are often cast as the villains in any discussion of sudden or unwanted exchange rate movements. This is not to suggest that the stories are untrue, or that speculative activity does not occasionally cause the exchange rate to move in an excessive or misguided manner; simply that there are few credible tests of this proposition. Absent a reliable exchange rate equation that can

Graph 3: Dynamic simulation - with debt

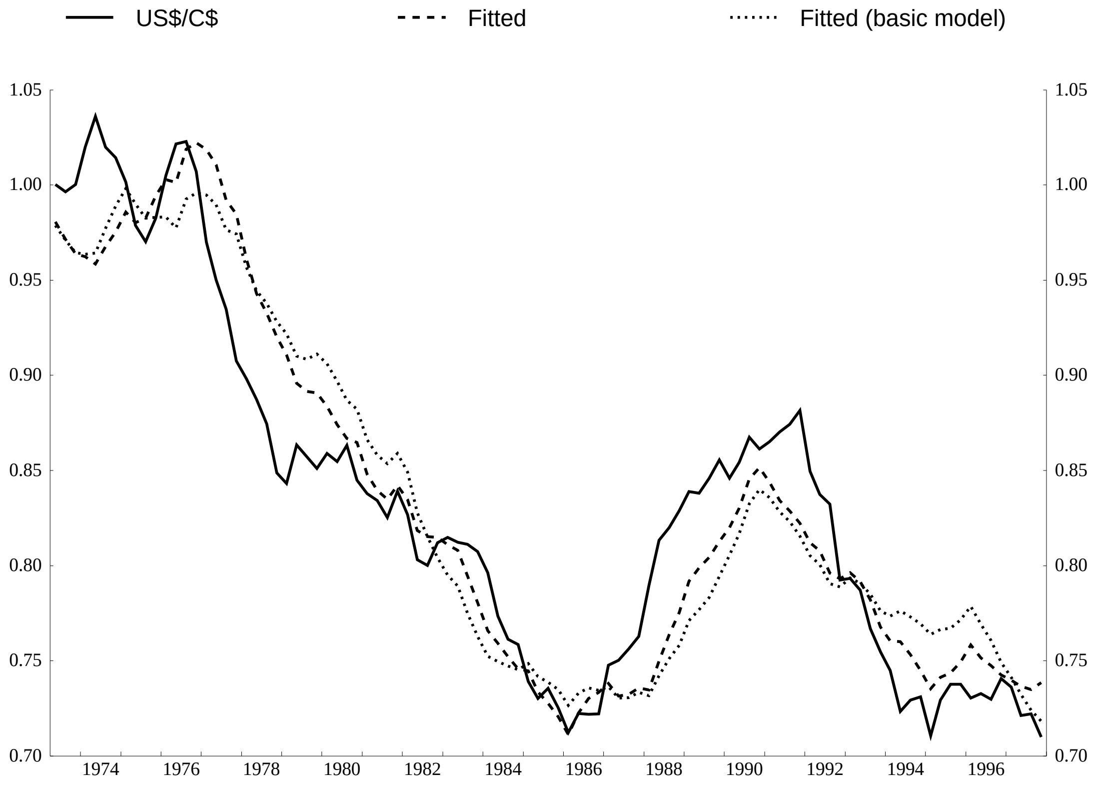


Graph 4: Dynamic simulation - with productivity



tell the authorities exactly where the currency should be at every point in time, it is impossible to make anything other than informed guesses about whether or not the exchange rate has deviated from its fair market value and what might have caused it.

Graph 5: Dynamic simulation - with productivity and debt



The issue of exchange rate overshooting is of critical concern to policymakers, who often worry that excessive volatility in exchange markets will spill over into domestic interest rates and prejudice the central bank's ability to control monetary conditions. Even when exchange rate movements are believed to be driven by fundamentals, there is a risk that sharp currency depreciations might become self-reinforcing, causing interest rates to jump and pushing monetary conditions much higher at a time when easier conditions would clearly be called for.[13, 14]

In periods such as this, it may be necessary for central banks to raise official short-term interest rates in a pre-emptive manner, in order to calm exchange markets and dampen extrapolative expectations. A tactical manoeuvre like this is undertaken, not because tighter monetary conditions are desired, but to avoid the more dramatic tightening that might otherwise occur if market expectations were to become destabilizing.

---

13 Given Canada's past record of exchange rate depreciation and uncertainty associated with financial market volatility, the Bank of Canada has been concerned for many years that there is little firm conviction in financial markets about the appropriate level for the Canadian dollar exchange rate. Consequently, when the Canadian dollar depreciated rapidly, the Bank often raised its Bank Rate in order to provide "comfort" to exchange market participants and contain the potential feedback effects on domestic interest rates. See Zelmer (1996) and Clinton and Zelmer (1997) for a more complete discussion of the tactical challenges confronting Canadian monetary policy.

14 In the past the Bank also feared that a marked exchange rate depreciation would spark an increase in inflation expectations, thereby putting upward pressure on nominal interest rates – see the 1985 Bank of Canada Annual Report. However, the introduction of inflation targets, and more importantly their achievement, appears to be providing a firmer footing for inflation expectations. The significant depreciation of the Canadian dollar in 1998 was accompanied by a narrowing of the spread between nominal and real return bond yields in Canada and longer-term private sector forecasts of inflation remained firmly rooted around the mid-part of the inflation central target range.

The Bank of Canada engaged in such an exercise in late August 1998, shortly after the collapse of the Russian rouble. The depreciation of the Canadian dollar had started to accelerate, domestic interest rates across the yield curve had moved sharply higher, and there was a growing sense of unease among market analysts and traders. During this episode, the overnight rate was raised by a full percentage point, after which financial markets appeared to calm and the overnight rate was gradually reduced.[15]

The key to any successful operation of this type is to know when destabilizing expectations are beginning to take hold and to apply just enough contractionary medicine to reverse the process. Once conditions have improved, interest rates can be lowered and authorities can guide the economy back to the desired monetary policy track. Ideally, central banks would like to have a model that could tell them exactly when these destabilizing episodes were about to occur. The model would be able to capture the joint effects of fundamentalists and speculative noise traders in the exchange market, and allow the central bank to gauge which group was exerting a stronger influence on the exchange rate at different points in time.

Robert Vigfusson, an economist at the Bank of Canada, developed such a model in 1996, based on a Markov-switching procedure. According to the model, the exchange rate that is actually observed in the market at any time is the result of a complex interaction between two types of agents – fundamentalists, who try to keep the exchange rate close to its true equilibrium value, and noise traders (or chartists), who often cause it to deviate from its fair market value. The actions of fundamentalists are assumed to be guided by the basic exchange rate equation described in Section 2. The fitted values that the equation provides represent the exchange rates that one would observe if the market were dominated by these equilibrating agents. Noise traders or chartists, in contrast, are assumed to operate on the basis of a simple rule of thumb, designed to detect shifts in market sentiment and the emergence of new support levels or trends in the exchange rate.

This joint exchange rate determination process is captured by the following equation, in which the expected change in the exchange rate is modeled as a weighted average of the expectations of these two groups:

$$(5) \qquad E\Delta s_{t+1} = \omega_t E\Delta s_{t+1}^{f} + (1-\omega_t) E\Delta s_{t+1}^{c}$$

where $E\Delta s$ = expected change in s, s = log of the nominal Canadian-US exchange rate, f,c = superscripts indicating fundamentalists and chartists, and ω = weight assigned to fundamentalists.

The equations describing the behavior of fundamentalists and chartists can be written as:

$$(6) \qquad \Delta s_t^{f} = \alpha^{f} + \phi(s_{t-1} - \tilde{s}_{t-1}) + \gamma intdif_{t-1} + \varepsilon_t^{f}$$

where $\tilde{s}$ = fundamentalists' forecast of s, α^f = a constant, and

$$(7) \qquad \Delta s_t^{c} = \alpha^{c} + \psi_{14} ma_{14} + \psi_{200} ma_{200} + \Gamma intdif_{t-1} + \varepsilon_t^{c}$$

where ma_{14} and ma_{200} = moving averages used by the chartists to forecast changes in s, and α^c = a constant.

The variables guiding the fundamentalists have already been discussed in detail in earlier sections of the paper. The only change that was introduced by Vigfusson was to convert quarterly data into a daily frequency using a cubic spline technique. The chartists' equation that he used assumes the following simple (but not unrealistic) behavioral pattern. Whenever the 14-day (short-term) moving average of exchange rates exceeds the 200-day (long-term) moving average, chartists are assumed to buy the

15 It must be conceded that on the day the Bank acted there were no immediate salutary effects on markets. The exchange rate remained weak that day and interest rate spreads across the yield curve widened out even further (see the empirical results contained in Muller and Zelmer (1999)). However, the situation improved shortly thereafter as expectations of a monetary easing by the Federal Reserve began to emerge and as commodity prices showed signs of stabilizing.

currency. If the 14-day moving average is lower than the 200-day moving average, the currency is sold.[16]

The transition equations in the Markov-switching process that link the two groups and assign a probability of being in regime *f* or *c* (i.e. fundamentalists or chartists) are:

$$(8) \qquad \rho(R_t / R_{t-1}) = \Phi(\alpha_f)$$

$$(9) \qquad \rho(R_t / R_{t-1}) = \Phi(\alpha_c)$$

where $\rho(R_t)$ is the probability of being in regime R.

Portfolio managers try to determine which group will dominate the market at different points in time, and adjust their own investment activities accordingly. The log likelihood function that they are assumed to maximize is represented by the following equation:

$$(10) \qquad LLF = \sum_{t=1}^{t}\sum_{t=1}^{t}\rho(R_t)d(s_t | R_t)$$

where $d(s_t|R_t)$ = the normal density function of the regime's residual.

A detailed discussion of the original results can be found in Vigfusson (1996) and Murray et al. (1996). The main elements can be summarized as follows. First, all the variables in the chartists' and fundamentalists' equations had their expected signs and were statistically significant.[17] Second, chartists appeared to dominate the market during tranquil periods – or about 70% of the time. Third, periods of "excess" volatility in the exchange market were typically dominated by fundamentalists, who tried to push the exchange rate back to its equilibrium value. Chartists, it seems, lent a certain inertial force to the market, which generally caused the exchange rate to move in a stable but not necessarily appropriate manner. In time, once the exchange rate had deviated sufficiently from its equilibrium value, fundamentalists would enter the market and (presumably) realize a profit by pushing the rate back to its appropriate level.

Table 6
Parameter estimates for the Markov-switching model (daily data)

January 1983–December 1992	f	θ	β	σ_f	α_f	
Fundamentalists	0.0001 (2.729)	0.0119 (2.243)	0.0002 (0.381)	0.0018 (26.371)	1.2656 (10.076)	
	c	ψ_{14}	ψ_{200}	Γ	σ_c	α_c
Chartists	0.0002 (1.573)	0.0070 (2.381)	–0.0079 (–2.677)	–0.0007 (–4.000)	0.0007 (33.634)	1.6784 (17.704)
January 1983–December 1998	f	θ	β	σ_f	α_f	
Fundamentalists	0.0001 (1.912)	0.0072 (3.098)	–0.0001 (–0.263)	0.0018 (58.448)	1.3778 (18.598)	
	c	ψ_{14}	ψ_{200}	Γ	σ_c	α_c
Chartists	0.0001 (1.341)	0.0062 (2.843)	–0.00070 (–3.032)	–0.0006 (–5.062)	0.0008 (48.729)	1.6735 (24.386)

Note: t-statistics in parentheses.

[16] While this might seem overly simplistic, it is modelled after practices that are actually followed in the market.

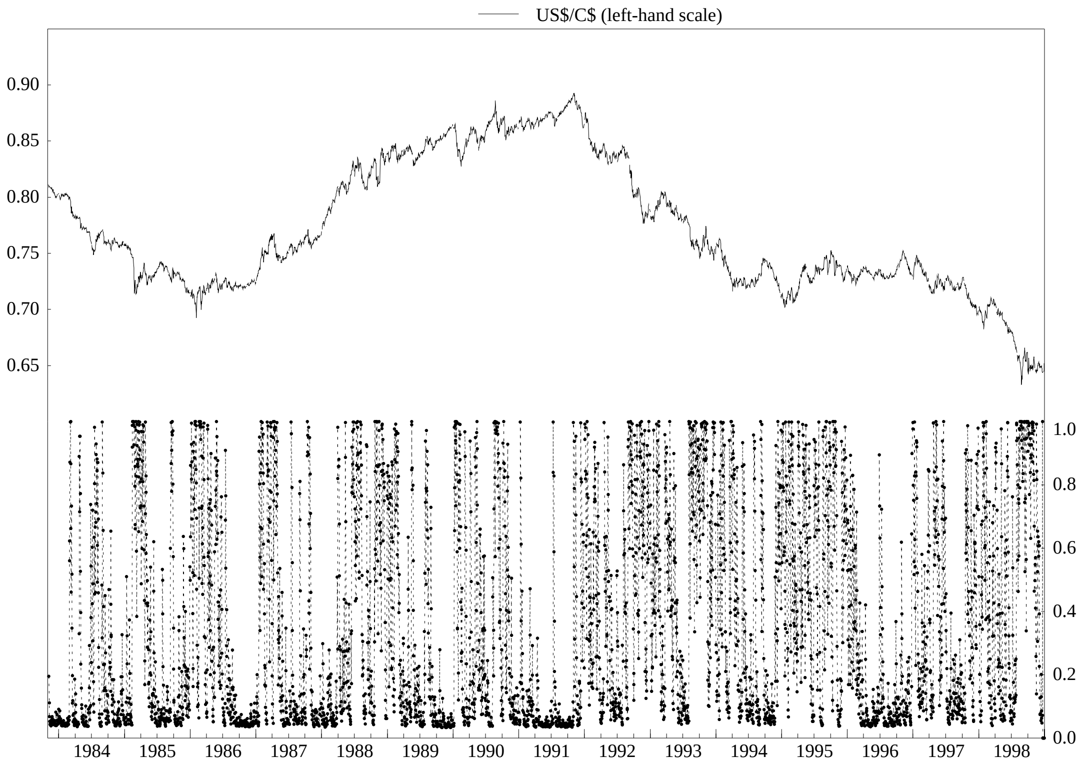
[17] *enetot* had a positive (perverse) sign, but this was expected from our earlier regressions.

Re-running the model with data drawn from the last three years should allow us to determine if the same qualitative results still obtain. More importantly, it will also allow us to determine if chartists as opposed to fundamentalists were in control of the market during the turbulent episodes of 1997 and 1998, when the Bank of Canada moved short-term interest rates higher in an effort to keep monetary conditions on an even track.

The results for both the original regression and the more recent time period are shown in Table 6. As the reader can see, parameter estimates for the two samples are virtually identical. Moreover, they remain correctly signed and statistically significant. While chartists still dominate the foreign exchange market on most trading days, these also tend to be the more tranquil periods, in which the exchange rate is trending smoothly upwards or downwards. Fundamentalists are more prominent during turbulent periods, in which the exchange rate displays greater volatility and moves in a more exaggerated manner.

Graphs 6 and 7 plot movements in the actual exchange against the probability that the market is dominated by either fundamentalists or chartists. A spike in the series shown in the bottom half of the graphs indicates a higher probability of being in a fundamentalist regime (or, conversely, a lower probability of being in a chartist regime). The two time periods in which the Bank of Canada entered the market to raise interest rates and help support the currency (1997Q4–1998Q1 and August 1998) appear to have been dominated by fundamentalists.

Graph 6: Exchange rate and probability of fundamentalist regime

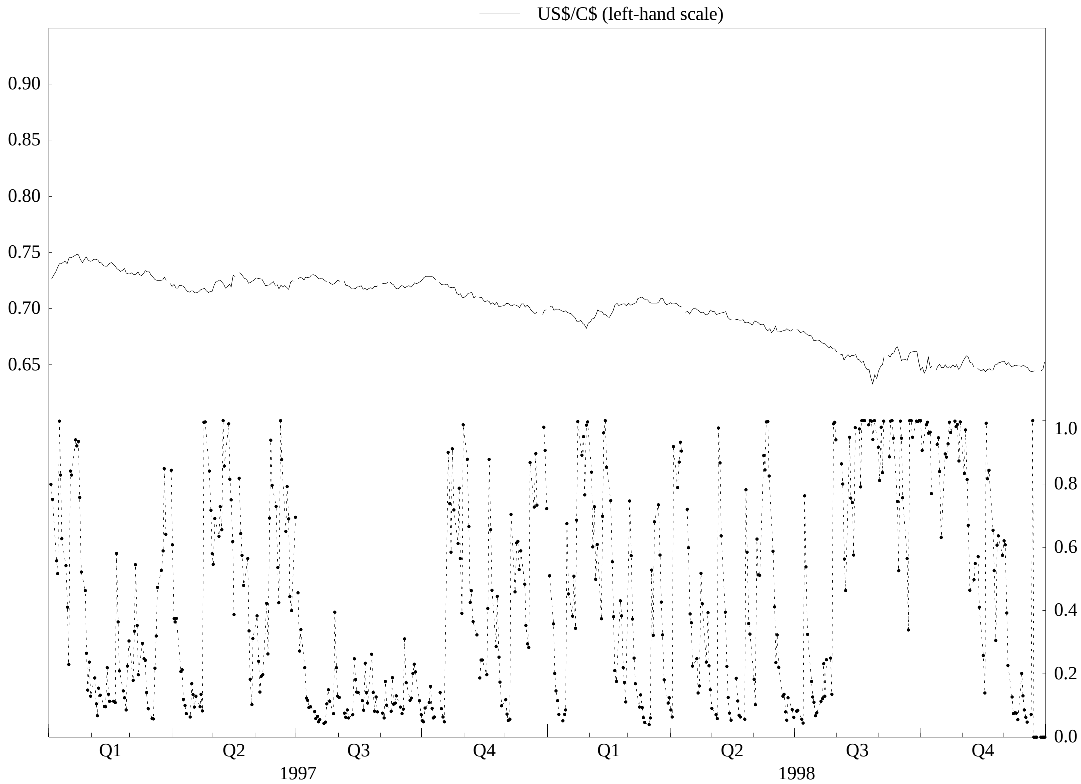


Note: The dotted line (right-hand scale) indicates the probability of being in a fundamentalist regime.

Anecdotal evidence in support of this more benign interpretation of recent events can be found in the trading volumes reported for various government securities and the Canadian dollar. The latter suggest that trading volumes were unusually heavy through this period (i.e. reduced market liquidity was not a problem) and that the ratio of interbank to customer business was not out of line with recent trends (i.e. dealers did not have any difficulty absorbing the large order flow and did not have to rely on the interbank market to take them out of positions). While bid-ask spreads widened through much of 1997 and 1998, and domestic interest rates peaked towards the end of August 1998, these developments were not peculiar to Canada and may have simply reflected a normal adjustment of the real risk premium during a period of increased uncertainty. (Graphs A1 through A9 in Appendix 3 document these changes in greater detail.)

It is important to note that this evidence and the empirical results reported above are only suggestive and cannot speak to the issue of whether or not the Bank of Canada's actions over this period were necessary or helpful. Had it not been for the tactical operations that were undertaken, it is possible that markets would have become seriously destabilized after the collapse of the Russian rouble. Since we cannot perform a true counterfactual experiment, we will never know. In the end, such tactical manoeuvres must always rely on judgment and gut instinct. Given the uncertain nature of the market through the latter part of August and early September 1998, one could regard the 1% increase in official interest rates as prudent insurance, which was unwound shortly thereafter and had little effect on the real economy. It also provided cover for the severe dislocations that were experienced in world financial markets immediately after the problems of Long-Term Capital Management became public.

Graph 7: Exchange rate and probability of fundamentalist regime

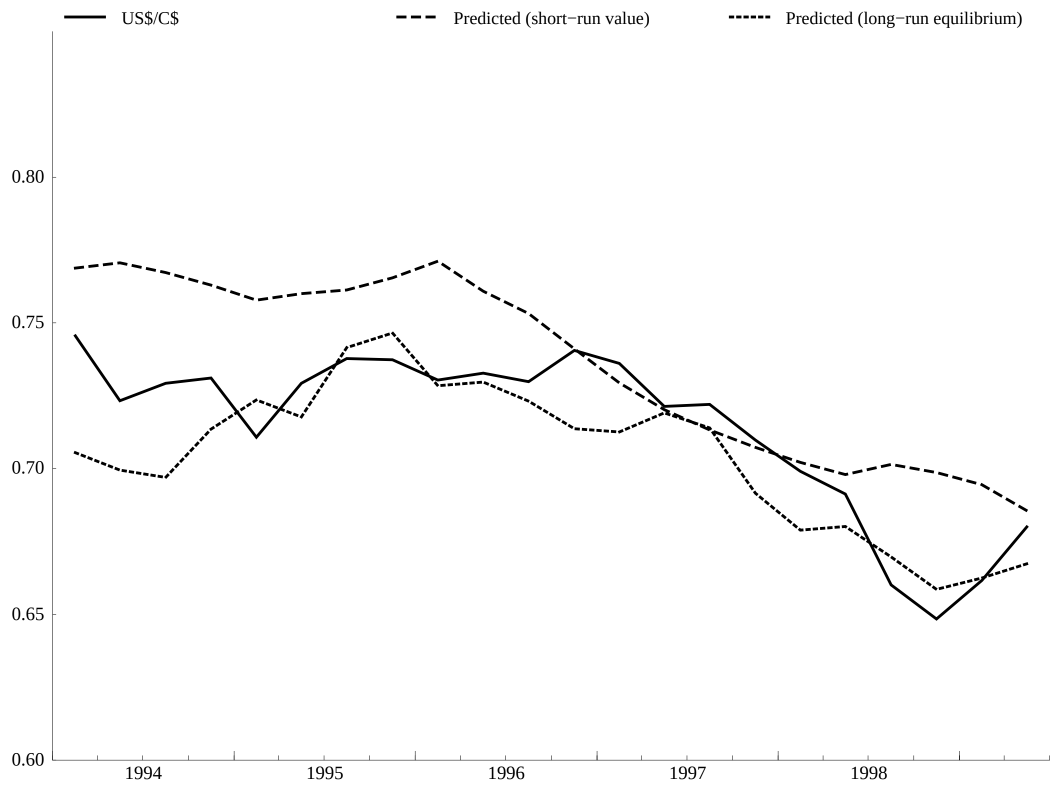


Note: The dotted line (right-hand scale) indicates the probability of being in a fundamentalist regime.

Another question that might be asked regarding the results of our work is how fundamentalists could be seen dominating the market at a time when the actual exchange rate appears to have been somewhat lower than the value predicted by our exchange rate equation (see, for example, Graph 2). More specifically, if the equation that the fundamentalists were using to guide their activities suggests that the dollar was undervalued, why, according to the regime-switching model, were they in the market driving it even lower? The answer hinges on the distinction between short-run and long-run equilibria. While the exchange rate equation captures the average speed of adjustment of *rfx* to external shocks, and indicates where the real exchange rate is expected to be at time *t*, there may be times when the speed of adjustment accelerates or becomes non-linear. The turbulent episodes described above may represent such periods. To give the reader a better idea of how this might operate, Graph 8 plots the actual exchange rate, its predicted short-run value, and its long-run equilibrium value. Viewed in this way, the seeming inconsistency between the results reported above and those reported in Sections 2 and 3 appears to disappear. While the actual exchange rate lies below the short-run values predicted by our model, it is very close to the long-run equilibrium values that the equation generates.

The main message from this work is that periods of volatility are not necessarily associated with instability and exchange rate overshooting. They may be the result of re-equilibrating forces that are trying to correct some earlier mispricing of the exchange rate. It could be a mistake, therefore, to automatically blame any sharp movements in *rfx* on destabilizing speculators.

Graph 8: Predicted short−run and long−run values



5. Policy lessons and conclusions

The empirical results reported in Sections 2, 3 and 4 do not provide any new or convincing evidence of exchange rate misbehavior over the most recent period. While the simulations in Section 2 indicate that the Canadian dollar *might* have been underpriced at certain times during the past two to seven years, the deviations between the actual and fitted values are typically quite small and may have been driven by fundamentals not captured in our simple equation. The determinants of the exchange rate are one of the most difficult things to model in economics, and precise judgments about where the dollar should be at any point in time are beyond our capability. The most significant result reported in the paper, however, is not the extent to which our currency might have been undervalued, but rather the large share of the Canadian dollar's movements that can be explained by two or three fundamental variables. For whatever comfort it provides, the basic equation indicates that the exchange rate is now close to (albeit still slightly below) its equilibrium value, given the fundamentals currently in place. Tests based on the regime-switching model described in Section 4 were also reassuring, and suggest that turbulent periods often coincide with necessary market corrections and should not, therefore, be a source of concern. Indeed, through much of the 1997–98 Asian and Russian crises, fundamentalists as opposed to chartists appeared to be guiding exchange rate movements.

The lessons that policymakers might take from this analysis are threefold. First, and most obviously, international financial crises are difficult, if not impossible, to predict. Any exchange rate forecast is risky and subject to a large margin of error, no matter how reliable the underlying equation might be. Second, most movements in the Canadian dollar (and, one hopes, other exchange rates) are guided by fundamentals as opposed to animal spirits. In an environment where inflation expectations are firmly anchored, policymakers should be wary of resisting them, and should instead consider adjusting their desired monetary policy track rather than automatically raising interest rates in response to any exchange rate pressure. Third, market turbulence does not necessarily imply exchange rate instability. Tactical manoeuvres, in which official interest rates are temporarily increased to support the exchange rate and calm market expectations, should be used sparingly, where such insurance is clearly necessary and the remedial interest rate increases can be quickly reversed.

Our future work in this area will concentrate on two topics. The first will involve a more comprehensive search for alternative explanatory variables that might improve the performance of our exchange rate equation. The second will involve further extensions and testing of Robert Vigfusson's regime-switching model, to see if it can be used to provide reliable real-time guidance to the Bank of Canada in its day-to-day operations.

Appendix 1

Unit root and cointegration tests on the original specification

Amano and van Norden began their search for a new and more reliable exchange rate equation in 1990 by first testing the dependent variable for stationarity. Their results showed that the real exchange rate was non-stationary in levels and was characterized by a unit root. Similar tests conducted over a somewhat longer sample period for purposes of the present paper appear to confirm these earlier results. Based on the Augmented Dickey-Fuller (ADF) tests shown in Table A1, we cannot reject the null hypothesis of a unit root for *rfx*.[18]

The fact that the dependent variable has a unit root is significant for at least three reasons. First, it implies that purchasing power parity does not hold – even in the long run. Second, it implies that cointegration techniques must be used in the analysis to avoid drawing incorrect and misleading inferences from the regression results. Third, it implies that only variables that are also integrated of order one, I(1), can play a role in determining the long-run behavior of the real exchange rate.

Unit root tests conducted on the three explanatory variables in our equation suggest that only *enetot* and *comtot* are I(1), while *intdif* is stationary in levels. As a result, only the first two variables can appear in the error-correction term. *intdif* has to be left outside the parentheses, influencing the short-term dynamics of the real exchange rate but not its long-run value.

Table A1
Tests for unit roots
(1973Q1–1997Q4)

Variable	No. of lags	ADF
rfx	3	–1.040
comtot	5	–1.801
enetot	3	–1.360
intdif	6	–3.280
5% critical value		–2.890
10% critical value		–2.580

If *enetot* and *comtot* are to play a critical role in determining the value of *rfx*, it is not sufficient simply to show that they have a unit root. We must also demonstrate that the dependent variable and the prospective explanatory variables are linked by a stable long-run relationship (or are cointegrated). Although several different approaches can be used to test for cointegration, the most popular and reliable method is the Johansen-Juselius test, which applies maximum likelihood estimation techniques to a full vector-autoregressive system of equations. The results of this test, estimated over the sample period 1973Q1 to 1997Q4, are shown below in Table A2.

Based on the λmax statistics reported in Table A2, only one cointegrating vector can be identified at the 5% critical value. (More specifically, we cannot reject the hypothesis that there are fewer than two cointegrating vectors.) There is no guarantee, however, that this vector links *enetot* and *comtot* to *rfx*. It is possible that the two explanatory variables are cointegrated with one another, and have no influence on the long-run behavior of *rfx*.

To check for this possibility, a separate Johansen-Juselius test was run just on *enetot* and *comtot*. Since no cointegrating vector was identified for these two variables (see Table A3), it appears that they are

[18] This is indicated by the fact that the ADF value shown opposite *rfx* is less than both the 5% and 10% critical values for the ADF test statistic.

only related to *rfx*. Because they are also found to be weakly exogenous, any estimation and inference that is conducted on equation (1) is equivalent to estimating a full system of equations in which *enetot* and *comtot* are also treated as separate dependent variables.[19] We do not have to worry, therefore, about any endogeneity or feedback running from the exchange rate to energy and non-energy commodity prices.

Table A2

Johansen-Juselius test for cointegration on *rfx*, *comtot* and *enetot*

No. of cointegrating vectors under the null hypothesis	λmax statistic	5% critical value
Fewer than 1	32.88	15.59
Fewer than 2	9.47	9.52
Fewer than 3	2.76	2.86
Test for weak exogeneity	LR test	Chi-square critical value
rfx	2.93	3.84
comtot	8.96	3.84
enetot	4.42	3.84

Note: Number of lags for J-J test = 20.

Table A3

Johansen-Juselius test for cointegration *comtot* and *enetot*

No. of cointegrating vectors under the null hypothesis	λmax statistic	5% critical value
Fewer than 1	6.34	9.52
Fewer than 2	4.45	2.86

Note: Number of lags for J-J test = 15.

[19] Weak exogeneity is tested at the bottom of Table 2 with the Chi-square statistic.

Appendix 2

Unit root and cointegration tests for the extended model

As with the original specification, it is important to determine if the new variables, *debtdif* and *proddif*, are stationary in levels or have unit roots. Tests based on the same Augmented Dickey-Fuller procedure that was used earlier in Section 2 indicate that both variables are I(1), and are therefore integrated of the same order as *rfx* (see Table A4).

Table A4
Tests for unit roots (1973Q4–1997Q4)

Variable	No. of lags	ADF
debtdif	8	–1.288
proddif	5	0.613
5% critical value		2.89
10% critical value		2.58

In order to improve the long-run explanatory power of the equation, it is also important that *debtdif* and *proddif* be cointegrated with *rfx*. When the Johansen-Juselius test was applied to the expanded variable list, a second cointegrating relationship was found. However, it is not obvious that the second vector indicates a long-run relationship between one or both of the new variables and the exchange rate. It is possible, as in the basic equation, that the two new variables are simply linked to one another. In order to test the nature of the relationship, separate cointegration tests were run on *debtdif* and *proddif*. The results are reported in Tables A5 and A6.

Table A5
Johansen-Juselius tests for cointegration on *rfx, comtot, enetot, debtdif* and *proddif*

No. of cointegrating vectors in the null hypothesis	Trace statistic	5% critical value
Fewer than 1	88.76	55.44
Fewer than 2	45.36	36.58
Fewer than 3	12.22	21.63
No. of cointegrating vectors under the null hypothesis	λmax statistic	5% critical value
Fewer than 1	43.40	27.62
Fewer than 2	33.15	21.58
Fewer than 3	9.29	15.59

Note: Number of lags for J-J test = 8.

Table A6
Johansen-Juselius tests for cointegration on *debtdif* and *proddif*

No. of cointegrating vectors under the null hypothesis	trace statistic	5% critical value
Fewer than 1	12.16	10.47
Fewer than 2	0.67	2.86
No. of cointegrating vectors under the null hypothesis	λmax statistic	5% critical value
Fewer than 1	11.49	9.52
Fewer than 2	0.67	2.86

Note: Number of lags for J-J test = 16.

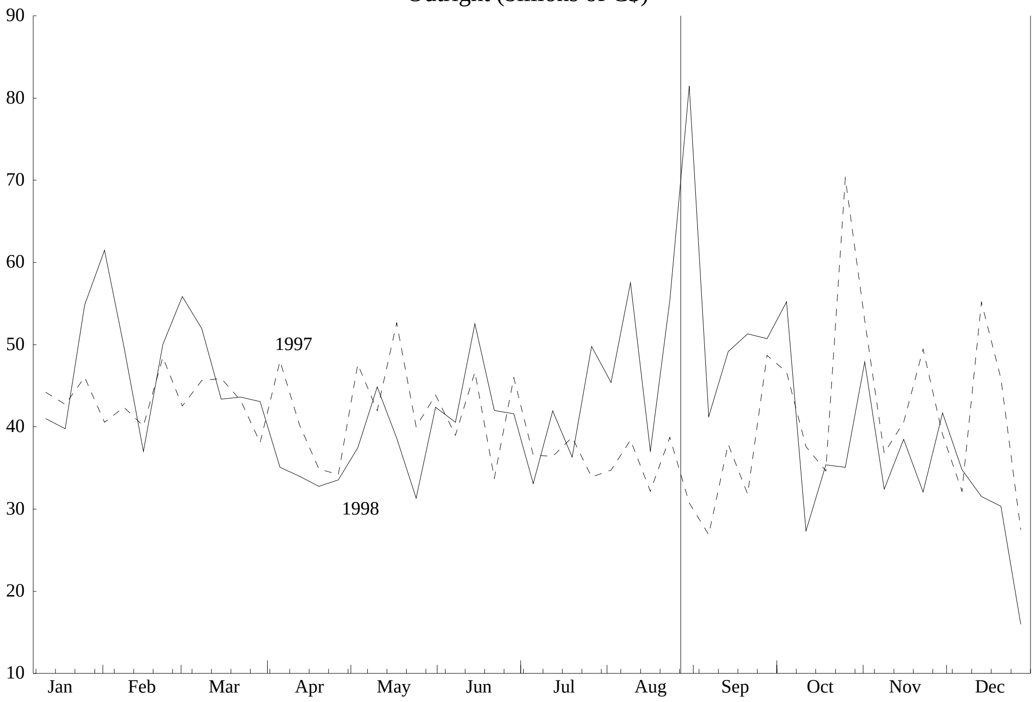
Based on the trace and λmax statistics, the two new variables appear to be related to one another as opposed to *rtf*. While there was not enough time to explore the nature of this relationship in any detail, it would not be surprising if the two were negatively correlated and if higher government debt was seen to cause lower productivity. Pierre St-Amant and David Tessier (1998) have shown in an earlier Bank of Canada Working Paper that higher trend rates of government spending in Canada than in the United States can explain much of the difference in the long-run rates of unemployment in the two countries. Although higher unemployment does not necessarily translate into lower productivity, productivity is known to be procyclical, and increased government regulation and spending are often believed to reduce potential output.

Appendix 3

Trading volumes and ratios of customer to interbank business for government of Canada securities and the Canadian dollar

Graph A1: Customer FX transaction volumes against the C$

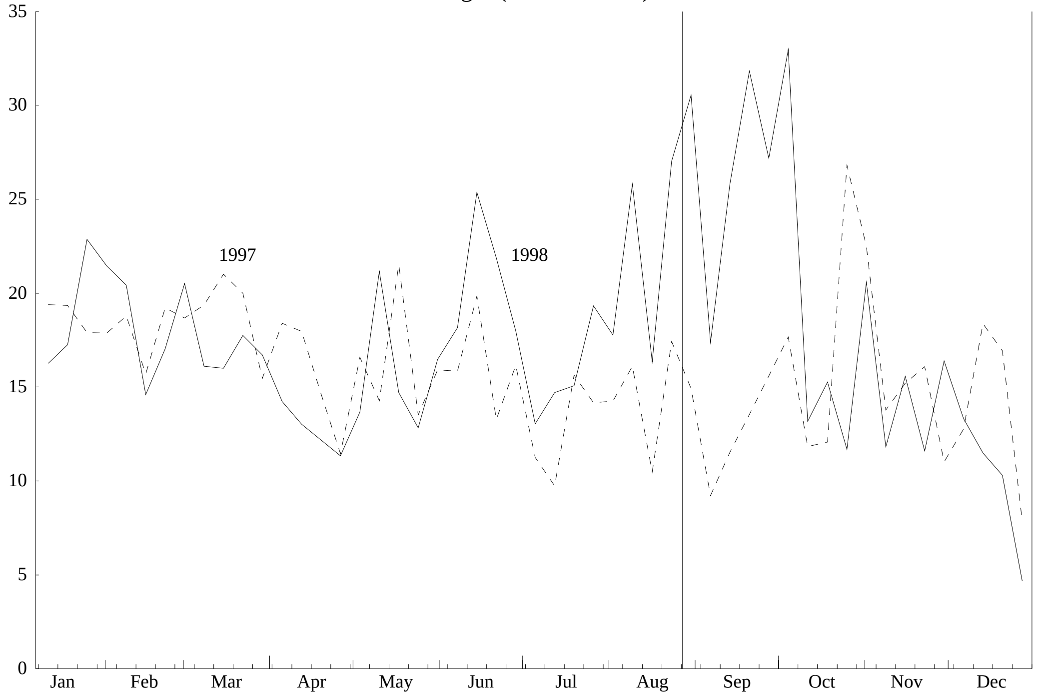
Outright (billions of C$)



Note: Vertical line corresponds to the August 1998 Bank Rate increase.
Source: Weekly transaction volumes reported by Canadian banks each Wednesday.

Graph A2: Interbank FX transaction volumes against the C$

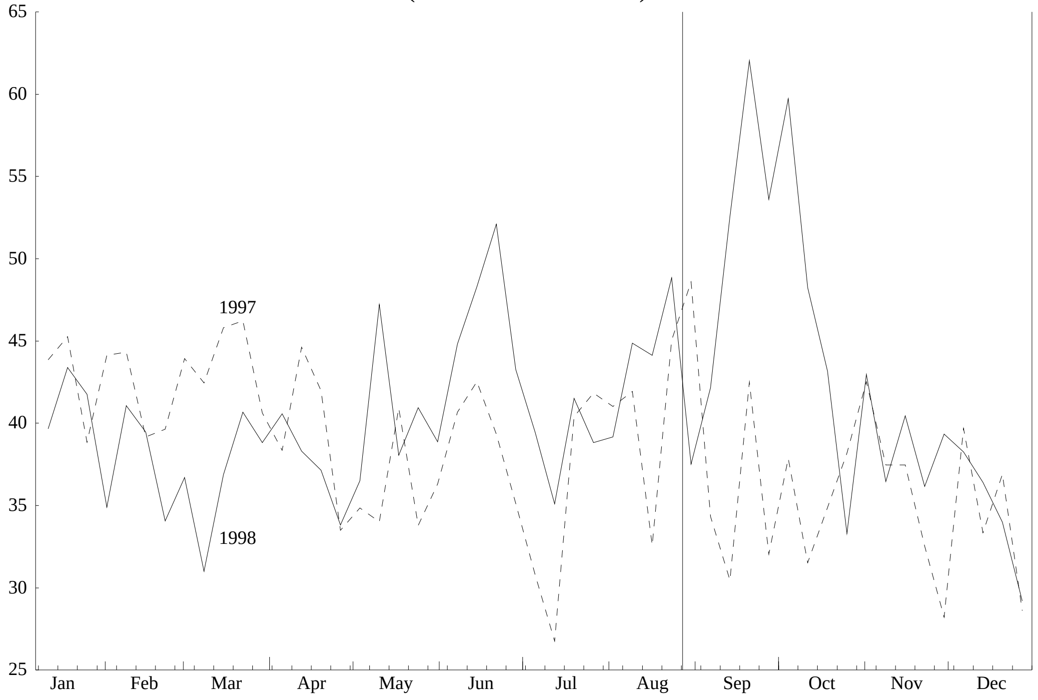
Outright (billions of C$)



Note: Vertical line corresponds to the August 1998 Bank Rate increase.
Source: Weekly transaction volumes reported by Canadian banks each Wednesday.

Graph A3: Interbank FX transaction volumes

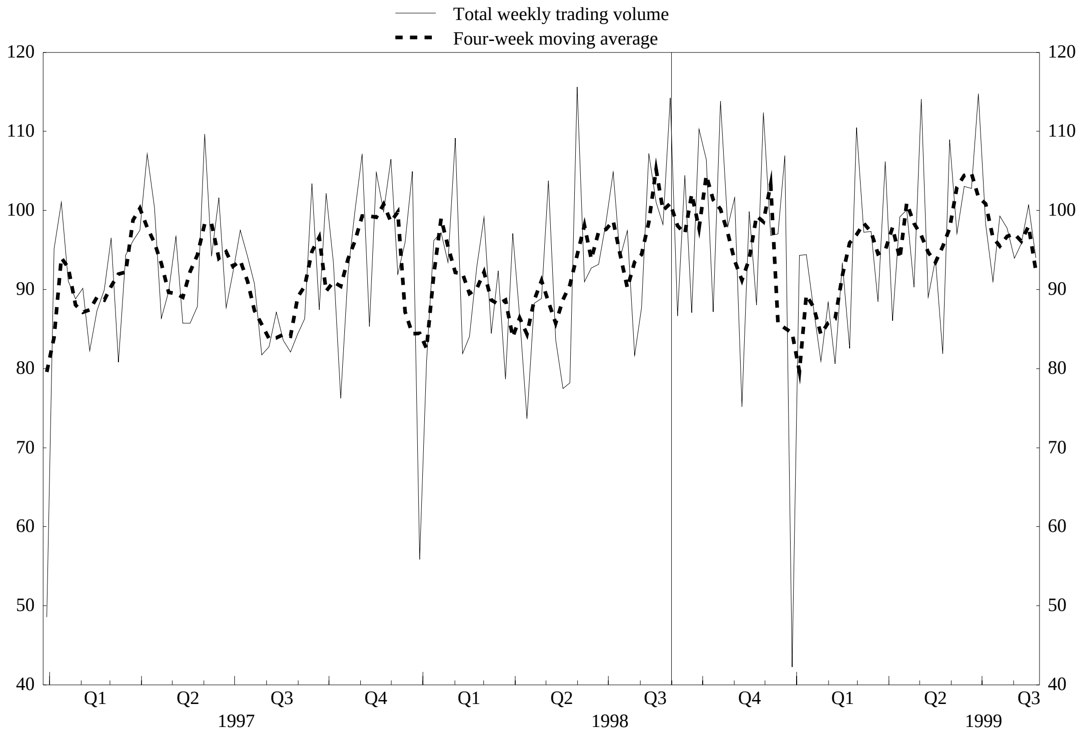
(% of customer volume)



Note: Vertical line corresponds to the August 1998 Bank Rate increase.
Source: Weekly transaction volumes reported by Canadian banks each Wednesday.

Graph A4: Government of Canada weekly T-bill trading volume

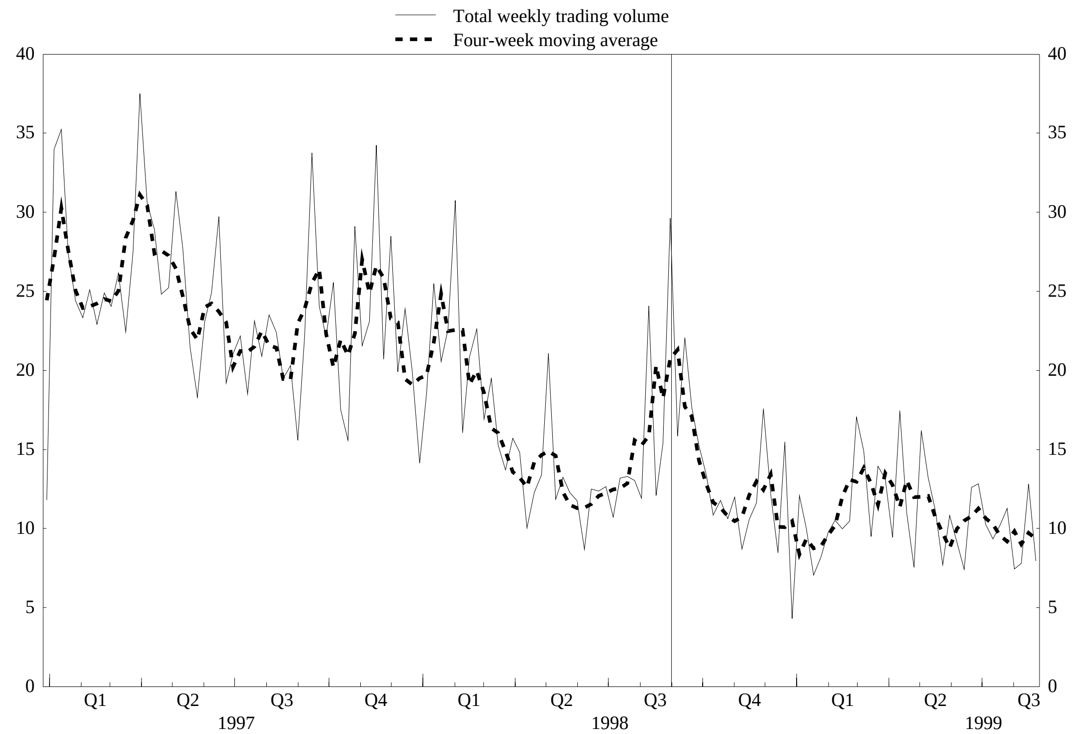
Customer (billions of dollars)



Vertical line refers to August 1998 Bank Rate increase

Graph A5: Government of Canada weekly T-bill trading volume

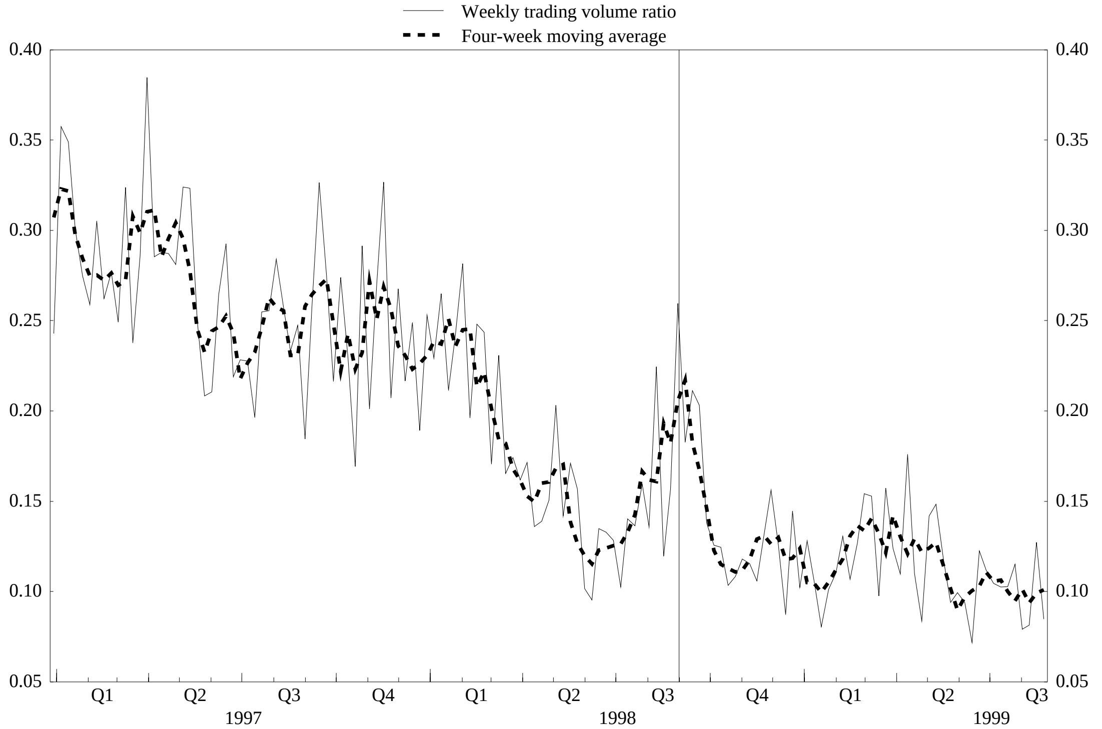
Interdealer (billions of dollars)



Vertical line refers to August 1998 Bank Rate increase

Graph A6: Government of Canada weekly T-bill trading volume

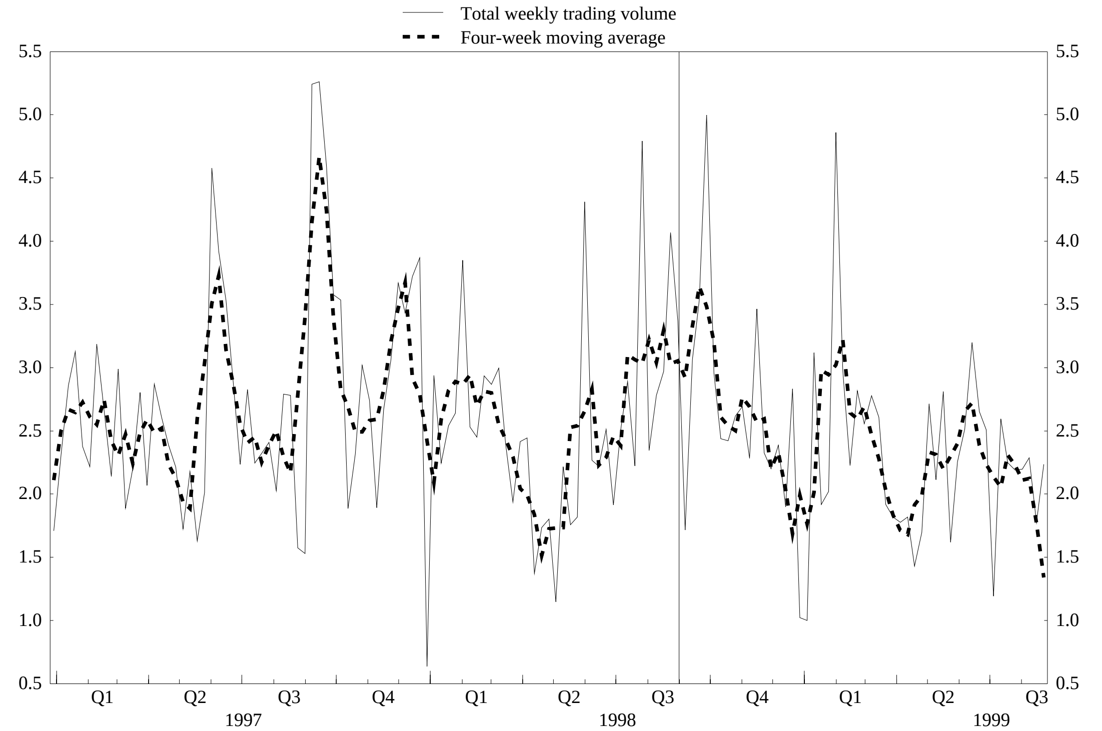
Ratio of interdealer to customer trading volume



Vertical line refers to August 1998 Bank Rate increase

Graph A7: Government of Canada weekly bond trading volume

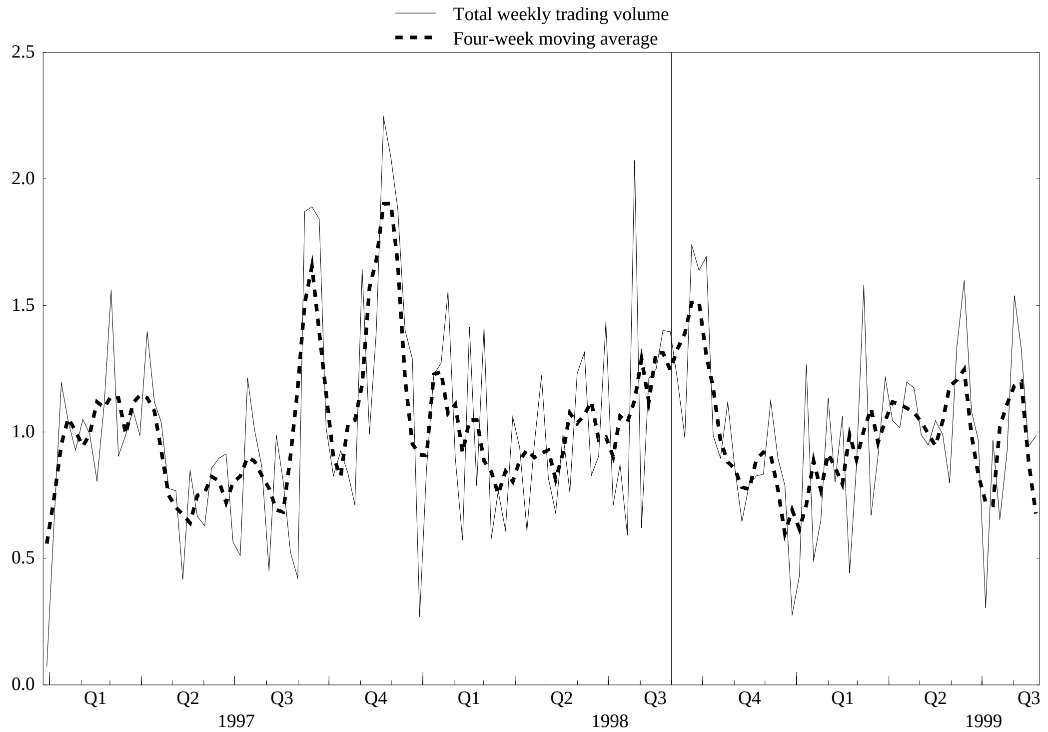
Customer (billions of dollars)



Vertical line refers to August 1998 Bank Rate increase

Graph A8: Government of Canada weekly bond trading volume

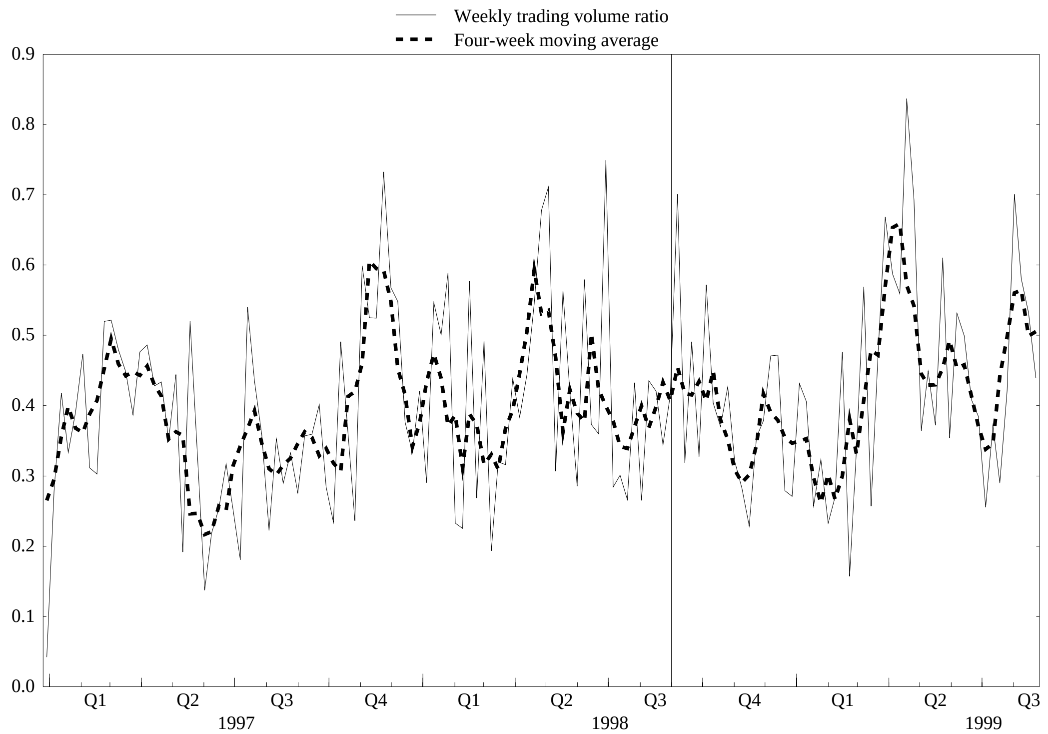
Interdealer (billions of dollars)



Vertical line refers to August 1998 Bank Rate increase

Graph A9: Government of Canada weekly bond trading volume

Ratio of interdealer to customer trading volumes



Vertical line refers to August 1998 Bank Rate increase

Bibliography

Amano, R and S van Norden (1993): "A Forecasting Equation for the Canada-U.S. Dollar Exchange Rate", in *The Exchange Rate and the Economy*, proceedings of a conference held at the Bank of Canada, 22–23 June 1992, Bank of Canada.

Clinton, K and M Zelmer (1997): "Constraints on the Conduct of Canadian Monetary Policy in the 1990s: Dealing with Uncertainty in Financial Markets". *Bank of Canada Technical Report*, No. 80.

Dickey, D A and W A Fuller (1979): "Distributions of the Estimators for Autoregressive Time Series with a Unit Root". *Journal of the American Statistical Association*, 74, pp. 427-31, June.

Dornbusch, R (1979): "Monetary Policy Under Exchange Rate Flexibility", in *Managed Exchange-Rate Flexibility: The Recent Experience*, Federal Reserve Bank of Boston Conference Series No. 20, Federal Reserve Bank of Boston.

International Monetary Fund: "World Economic Outlook". October 1996, May 1997 and August 1999.

Johansen, S (1988): "Statistical Analysis of Cointegration Vectors". *Journal of Economic Dynamics and Control*, 12, pp. 231-54, June-September.

Johansen, S and K Juselius (1990): "Maximum Likelihood Estimation and Inference on Cointegration with Applications to the Demand for Money". *Oxford Bulletin of Economics and Statistics*, 52, pp. 169-210, May.

McCallum, J (1998): "Government Debt and the Canadian Dollar". Royal Bank of Canada Current Analysis, Vol. 2, No. 10, September.

Macklem, T (1993): "Terms of Trade Shocks, Real Exchange Rates Adjustment, and Sectoral and Aggregate Dynamics", in *The Exchange Rate and the Economy*, proceedings of a conference held at the Bank of Canada, 22–23 June 1992, Bank of Canada.

Muller, P and M Zelmer (1999): "Greater Transparency in Monetary Policy: Impact on Financial Markets". *Bank of Canada Technical Report*, No. 86.

Murray, J, S van Norden and R Vigfusson (1996): "Excess Volatility and Speculative Bubbles in the Canadian Dollar: Real or Imagined?" *Bank of Canada Technical Report*, No. 76.

Orr, D (1999): "Why Do Such Bad Things Happen to Such a Good Economy?" WEFA Canada, May.

Rubin, J and P Buchanan (1996): "Do Fundamentals Justify An 80 Cent C$?" Wood Gundy *Economics Occasional Report*, No. 16, 3 December.

St-Amant, P and D Tessier (1998): "Tendance des dépenses publiques et de l'inflation et évolution comparative du taux de chômage au Canada et aux États-Unis". *Bank of Canada Working Paper*, No. 98-3.

Tessier, D and R Djoudad (1999): "Certaines évidences empiriques relatives à l'évolution du taux de change Canada/É.U." Bank of Canada, February.

Vigfusson, R (1996): "Switching Between Chartists and Fundamentalists: A Markov–Switching Approach". *Bank of Canada Working Paper*, No. 96-1.

Zelmer, M (1996): "Strategies Versus Tactics for Monetary Policy Operations", in *Money Markets and Central Bank Operations*, proceedings of a conference held by the Bank of Canada, November.

ISSN 1026-3993
ISBN 92-9131-099-9