AUSTRALIAN FINANCIAL MARKET VOLATILITY: AN EXPLORATION OF CROSS-COUNTRY AND CROSS-MARKET LINKAGES

Tro Kortian and James O'Regan

Research Discussion Paper
9609

November 1996

Economic Research Department

Reserve Bank of Australia

We would like to thank Malcolm Edey for his helpful comments and suggestions. Special thanks are due to Tasi Savva and Evelyn McCarron of Economic Group Publications, for their patience and assistance in the preparation of this document. The views expressed in the paper are those of the authors and should not be attributed to the Reserve Bank of Australia.

Abstract

This paper examines the behaviour of daily asset price movements in Australian bond, share and foreign exchange markets over the period 1987 to 1996, and addresses four questions concerning volatility and international market linkages. First, is there evidence of a trend increase in volatility in Australian financial markets? Second, have Australia's financial markets become more responsive to developments in counterpart foreign markets, and if so, what are the predominant foreign influences? Third, have international influences been more or less important than domestic cross-market influences? Fourth, is there evidence of directionality and other asymmetries in Australian financial market volatility?

The paper finds no compelling evidence to suggest the presence of a trend increase in volatility over the period. Evidence does exist, however, of quite significant cross-country 'contagion' or 'spillover' effects on Australia's bond and equity markets. For both of these markets, the predominant foreign market influence appears to be the US. Australian bond and share market volatility is found to be higher in bear markets than in bull markets, and higher following a market fall than a market rise. Evidence supporting the presence of asymmetries in the correlation of volatilities across markets is also documented.

JEL Classification Numbers F30, G10, G15

Table of Contents

AUSTRALIAN FINANCIAL MARKET VOLATILITY: AN EXPLORATION OF CROSS-COUNTRY AND CROSS-MARKET LINKAGES

Tro Kortian and James O’Regan

1. Introduction

Several episodes of quite severe market turbulence have occurred in financial markets over the last decade. The sharp and widespread fall in international bond prices witnessed in 1994 is one of the more recent episodes. Other prominent events include the stock-market crash of 1987, the ERM crises of 1992 and 1993, and the 1994-95 Mexican peso crisis and subsequent ‘Tequila’ effect. Such episodes have been interpreted by some observers as evidence of a change in the behaviour of present-day financial markets. In particular, assertions that financial markets are now characterised by higher levels of volatility than in the past, and display greater susceptibility to ‘contagion’ and ‘spillover’ effects, have acquired considerable prominence in recent years.

In this paper we examine the behaviour of daily asset price movements in Australian bond, share and foreign exchange markets over the period since 1987 and address several key questions. First, is there evidence of a trend increase in Australian financial market volatility over the period? Second, what are the predominant foreign influences on Australia’s financial markets, and have these influences become more important over time? If so, what are the predominant foreign influences? Third, have international influences been more or less important than domestic cross-market influences? Fourth, is there evidence of directionality and other asymmetries in Australian financial market volatility?

The paper is organised in the following manner.

Section 2 documents the volatility of daily price changes in the bond, share and foreign exchange markets in Australia, the United States, Japan, Germany and the United Kingdom over the period 1987-1996. This section also undertakes preliminary investigations into the extent of international linkages between markets.

Correlations of both daily volatility and daily price changes in the different country markets are presented, and their variations over the sample period examined.

Section 3 presents results from some simple econometric analysis further investigating the importance of cross-country linkages. It assesses the extent to which developments in foreign bond and equity markets influence the size and direction of daily price changes in the Australian counterpart markets.

Section 4 extends the empirical examination undertaken in the previous section by exploring cross-market as well cross-country linkages between Australian and US financial markets.

Section 5 examines issues relating to the directionality of volatility and other asymmetries in Australian financial market volatility. Specifically, it addresses questions such as: is volatility higher in 'bear' markets than in 'bull' markets; do market falls cause greater volatility than market rises; and do the cross-country and cross-market correlations between volatility vary during periods of market turbulence?

A summary of the paper's main findings and concluding comments is presented in Section 6.

2. Bond, Share and Foreign Exchange Markets: Descriptive Statistics and Correlations

This section examines the volatility in bond, share and foreign exchange markets in Australia, the United States, Japan, Germany and the United Kingdom over the period from May 1987 to February 1996. It also takes a preliminary look at the international linkages between markets using simple correlations.

All of the analysis is based on moving samples of daily price data to capture time variations in volatility measures and relationships through time. Rolling correlations across markets are calculated using a 250-day moving window of observations.[1]

---

[1] The rolling correlations are calculated using a 250-day moving window. The time-zone differences between the various markets present a problem for data synchronisation. As the

Volatility is measured using an exponentially weighted rolling standard deviation of daily percentage changes in the market level observed over the preceding 60 working days.[2] For share markets, the daily percentage change is calculated from the closing value of the relevant share price index. For the foreign exchange market, we use the daily percentage change in the rates quoted at 15.00 New York (Eastern) Time by Bankers Trust. In bond markets, however, volatility is calculated for daily basis point changes in 10-year benchmark bond yields.[3] This preliminary analysis focuses on questions of whether financial markets have experienced any major changes in volatility or in the degree of cross-country linkage, within the period studied.

2.1 Bond Markets

2.1.1 Volatility

Historical volatilities for bond markets in the five countries are plotted in Figure 1. Summary statistics are presented in Table 1.

It is apparent from Figure 1 that bond volatility, both in the Australian and foreign markets, has two key attributes. First, the volatility is not constant, but fluctuates substantially over time. Second, it exhibits *clustering*, that is, there exist periods of

---

Australian *day t* occurs before *day t* in the other markets, the data from other markets are lagged one day when calculating the correlations. For example, the Australia-US correlations are between Australia *day t* and US *day t-1*. Given the minimal time difference between Australia and Japan, Japanese data are not lagged. Hence the Australia-Japan correlations are between Australia *day t* and Japan *day t*.

2 In calculating the standard deviation, which is used as a measure of volatility, the observations are exponentially weighted, placing relatively more weight on recent observations. The weight allocated to each observation is $w_j = (1 - l)\, l^j$ where $l = 0.89125$. All of the data were obtained from *Datastream*.

3 Observations are mid-points between closing-time bid and offer prices. Basis point changes are simply the daily change in yields: $Basis\ Point\ Change_t = Yield_t - Yield_{t-1}$. The usual definition of basis point changes produces values exactly one hundred times larger than those generated here, but, as this makes no difference to the results, the term basis point changes is adopted for convenience.

heightened turbulence, often followed by longer periods of subdued or moderate volatility.

Figure 1: Bond-Market Volatility

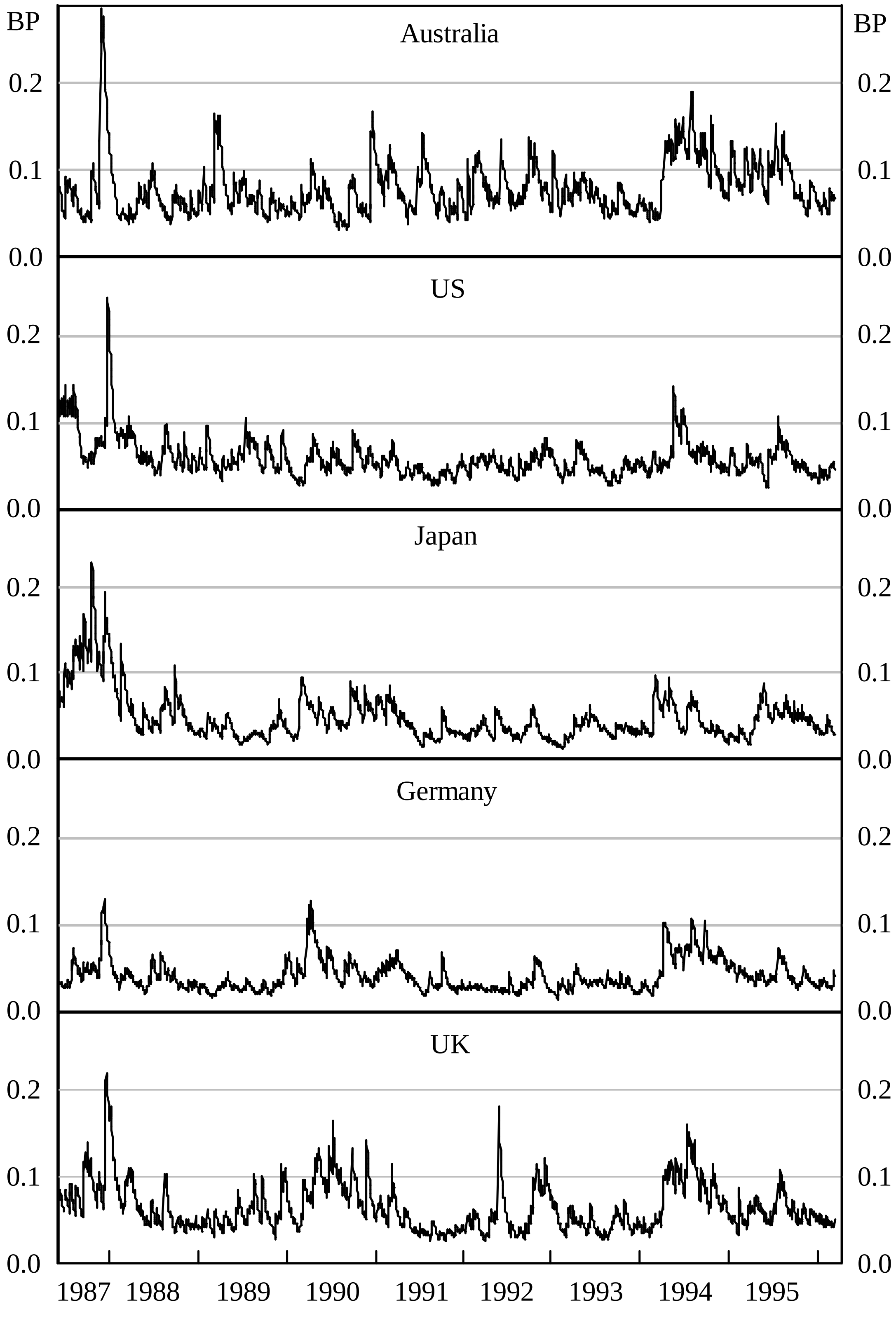


Table 1: Bond-Market Volatility (Feb 1987-Feb 1996)
Daily basis point changes

	Australia	US	Japan	Germany	UK
Maximum	0.28	0.24	0.23	0.13	0.22
Highest 5%	0.13	0.09	0.11	0.07	0.12
Average	0.08	0.06	0.05	0.04	0.06
Standard deviation	0.031	0.021	0.028	0.018	0.028
Lowest 5%	0.04	0.03	0.02	0.02	0.03
Minimum	0.03	0.02	0.01	0.01	0.03
Tension[(a)] coefficient (i)	3.08	2.74	5.23	3.52	3.48
Tension coefficient (ii)	4.80	4.63	9.98	5.85	5.58

Note: (a) The tension coefficient measures the tension between the volatility peaks and troughs in a given series. Tension coefficient (i) is defined as the ratio of a volatility series' 95-percentile value to its five-percentile value. Tension coefficient (ii) is defined in a similar manner, except that it relates to the ratio of the 99-percentile value to the one-percentile value.

Several other facts emerge from the international comparisons.

- Australian bond-market volatility appears high in comparison to other countries. Over the period February 1987 to February 1996, Australia had the highest average level of bond volatility. It clearly exceeded the levels recorded for the US, Japan and the UK, and was more than double that which is experienced by the German bond market over the period. This may be related to higher average levels of bond yields in Australia compared to the other countries, in turn related to historically higher and more variable inflation in the 1970s and 1980s.

- Bond market volatility displays greater variability in Australia than in other countries. As Table 1 indicates, Australian bond-market volatility exhibits the largest fluctuations around its mean or average level for the period.

- A slight rising trend in volatility can be discerned over the period for the Australian bond market, although this result may be dominated by the 1994 episode. Time trends fitted to the volatility profiles of each market reveal that Australia is the only country that records a significant positive trend. Volatility profiles for the US, Japan and UK markets were found to contain significant, but negative, time trends.[4]

- The magnitude and persistence of volatility triggered by the 1994 bond market collapse was higher in Australia than in other countries, with the next strongest reaction in the UK. It may be significant that these are the two countries in the sample with relatively poor inflation records, which may have contributed to higher perceived inflation risks and more volatile expectations of inflation.

2.1.2 Correlations and market linkages

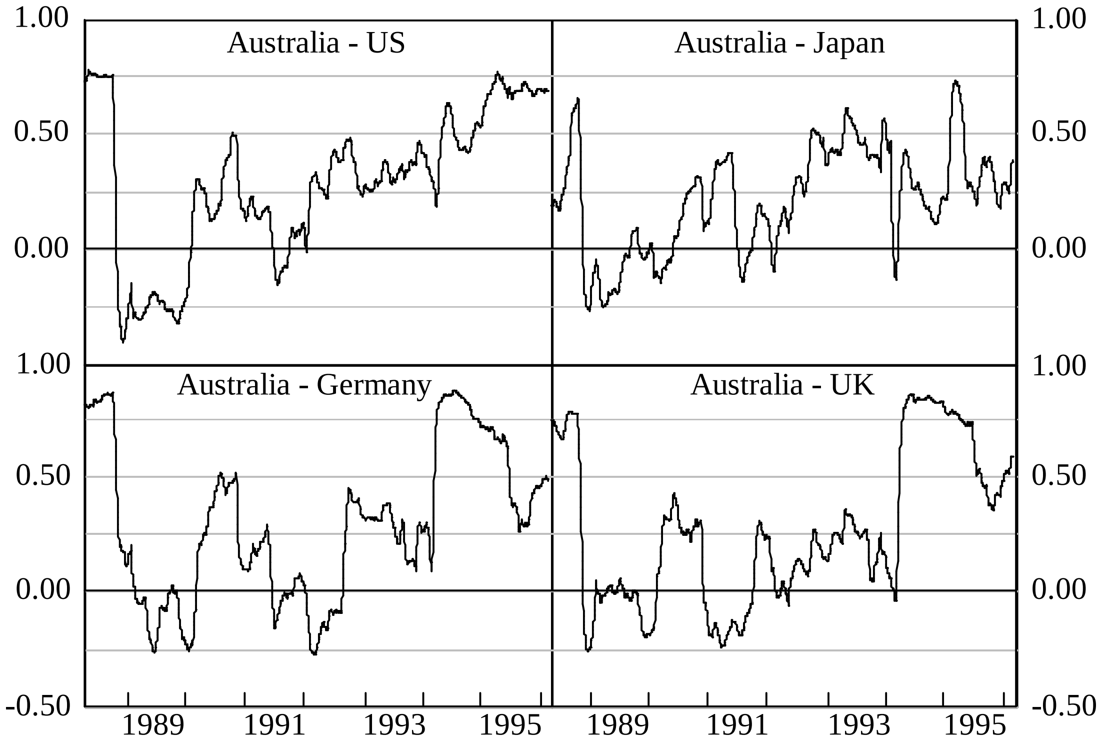
Rolling correlations between the volatilities in Australia and other countries are shown in Figure 2. In three of the four cases, these correlations have increased over time.[5] This suggests growing interdependence between bond markets during the 1990s, at least with respect to volatility. The growth in correlation is most striking in the Australia-US relationship, with the pick-up in correlation most evident from 1992.

---

4 Germany had a positive, but not statistically significant, trend. One question is whether the negative trends were secular trends, or essentially a result of the 1987 volatility surge. The regressions were re-run with the sample starting in 1988 to avoid the effects of the 1987 surge. In the second set of regressions, Germany joins Australia in having a significant positive trend, and the UK ceases to have a significant trend. The US and Japan retain their negative trends.

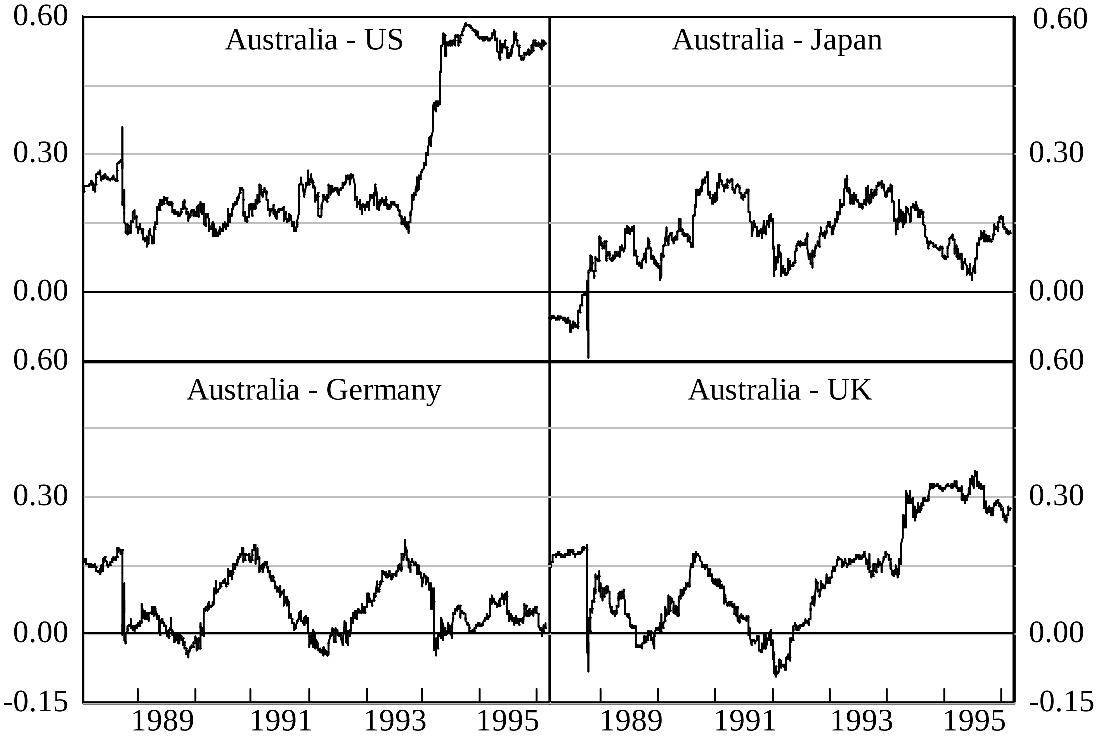
5 Japan was the exception: in the 1990s its correlation with Australia was constant.

Figure 2: Bond-Market Volatility – Rolling Correlations



Even more pronounced in the Australia-US relationship is the correlation between changes in daily bond yields. Figure 3 contains the rolling 250-day correlation of basis point changes between the Australian and other bond markets. While the correlations between basis point changes are understandably generally lower than those for volatilities, the trends evident in Figure 2 (rolling correlation of volatilities) are broadly similar to those contained in Figure 3 (rolling correlations of basis point changes). The most dramatic correlation profile in Figure 3 relates to the Australia-US pairing. Between late 1988 and late 1993 the correlation between basis point changes in Australian and US bond yields displays remarkable stability, fluctuating between around 0.15 and 0.25. It subsequently undergoes a rapid and substantial increase, rising from 0.15 to 0.55. The correlation remains at 0.55 for the rest of the sample, again displaying very little variation.

Figure 3: Rolling Correlations of Daily Basis Point Changes in Bond Yields



2.2 Share Market

2.2.1 Volatility

Table 2 presents summary statistics on share-market volatility and Figures 4a and 4b plot the volatility series for each market.[6] As with bonds, volatility displays persistence and is not constant over time. Share-market volatility could be characterised as generally steady but punctuated by brief volatile episodes: some countries experienced more of such episodes than others.

---

6 Figure 4a plots the volatility profiles over the entire sample period, whereas Figure 4b covers the period 1988-1996, thereby excluding the very large movements associated with the 1987 stock-market crash.

Table 2: Share-Market Volatility (Feb 1987-Feb 1996)
Daily percentage changes

	Australia	US	Japan	Germany	UK
Maximum	9.05	8.24	5.57	4.56	5.54
Highest 5%	1.19	1.44	2.33	2.12	1.26
Average	0.82	0.80	1.15	1.00	0.79
Standard deviation	0.654	0.622	0.655	0.570	0.436
Median	0.71	0.68	1.00	0.86	0.71
Lowest 5%	0.45	0.40	0.45	0.49	0.47
Minimum	0.30	0.29	0.27	0.30	0.34
Tension[(a)] coefficient (i)	2.64	3.63	5.23	4.31	2.69
Tension coefficient (ii)	10.75	9.25	9.22	9.87	6.79

Notes: *(a)* The tension coefficient measures the tension between the volatility peaks and troughs in a given series. Tension coefficient (i) is defined as the ratio of a volatility series’ 95-percentile value to its five-percentile value. Tension coefficient (ii) is defined in a similar manner, except that it relates to the ratio of the 99-percentile value to the one-percentile value.

A number of points may be made about share-market volatility.

- With the exception of Japan, volatility was more subdued in the second half of the sample period. While the level of background volatility seemed unaffected, there were fewer surges in volatility in the latter years.

  This observation is confirmed by simple regressions which reveal that every country except Japan had a negative time trend in its volatility. This result remains unchanged when the regressions are re-run starting at July 1988 to exclude the effects of the 1987 stock-market crash. Japan had a positive time trend in each set of regressions.

- The 1987 surge in volatility following the October stock-market crash dominates the series. In Australia and the US the reaction was much stronger than in other markets. The peak of the surge was over ten times the sample average volatility for these countries: this compares with over seven times in

Figure 4a: Share-Market Volatility (1987-1996)

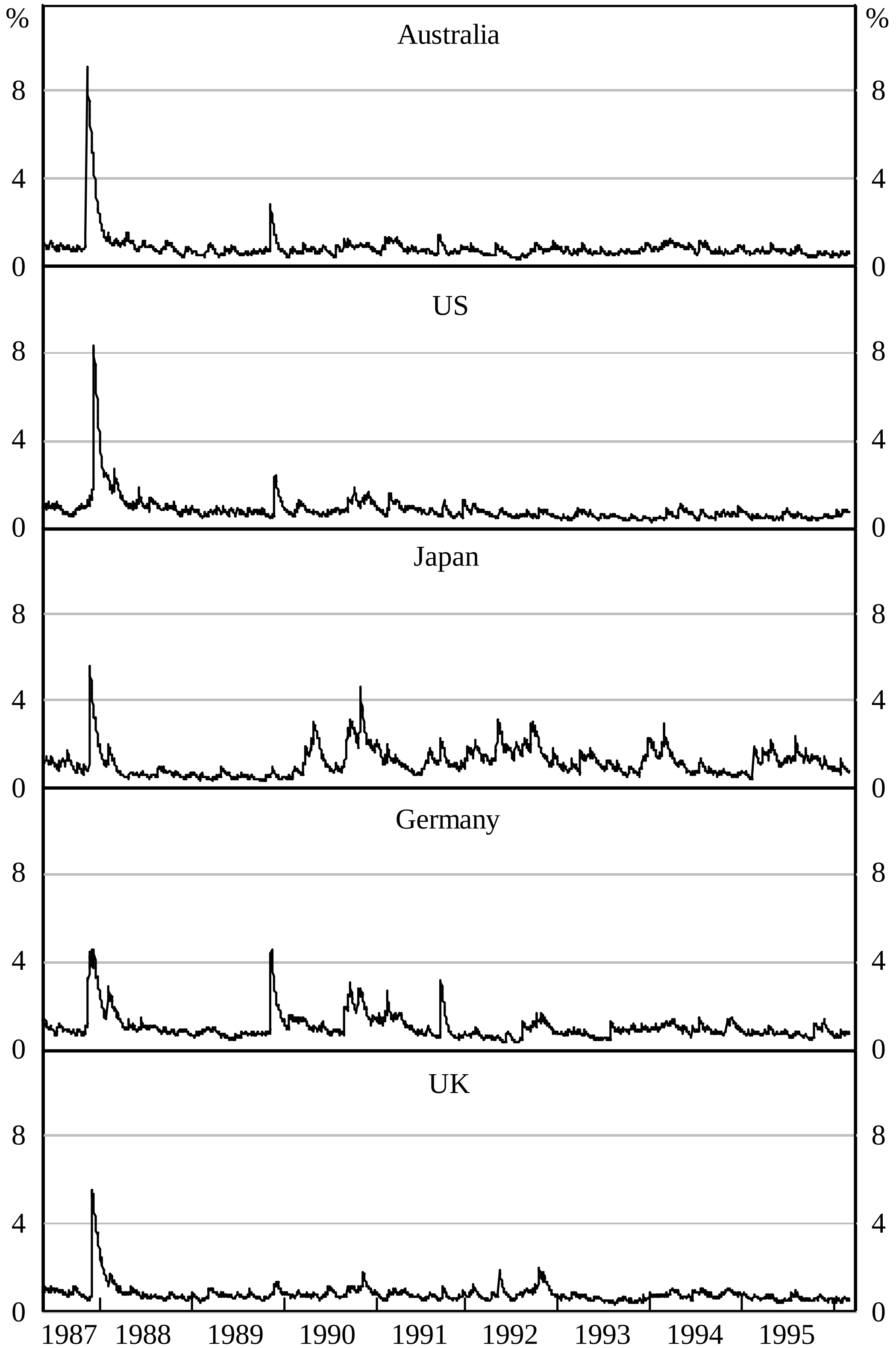
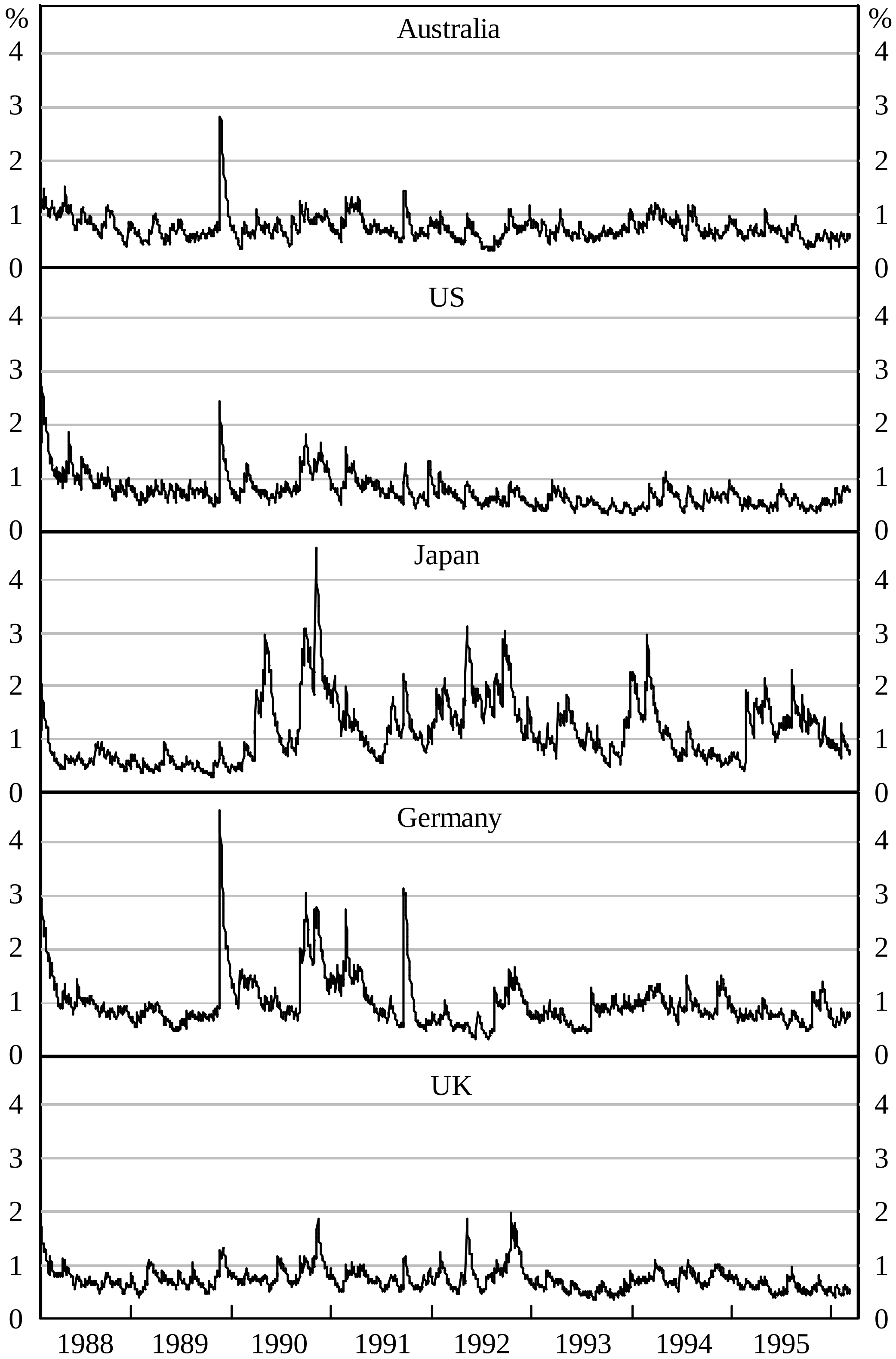


Figure 4b: Share-Market Volatility (1988-1996)



the UK, 4.8 in Japan and 4.5 in Germany. The extremity of the 1987 episode manifests itself in the large difference between the two tension coefficient values for each of the markets, but especially for Australia.

- The mini stock-market crash in 1989 occasioned another notable surge in volatility in several countries. In Australia and the US it is the only outstanding peak of volatility apart from 1987, and in Germany it is the highest episode of volatility, exceeding even 1987. In Japan and the UK, however, it barely registers, prompting only very slight increases in volatility.

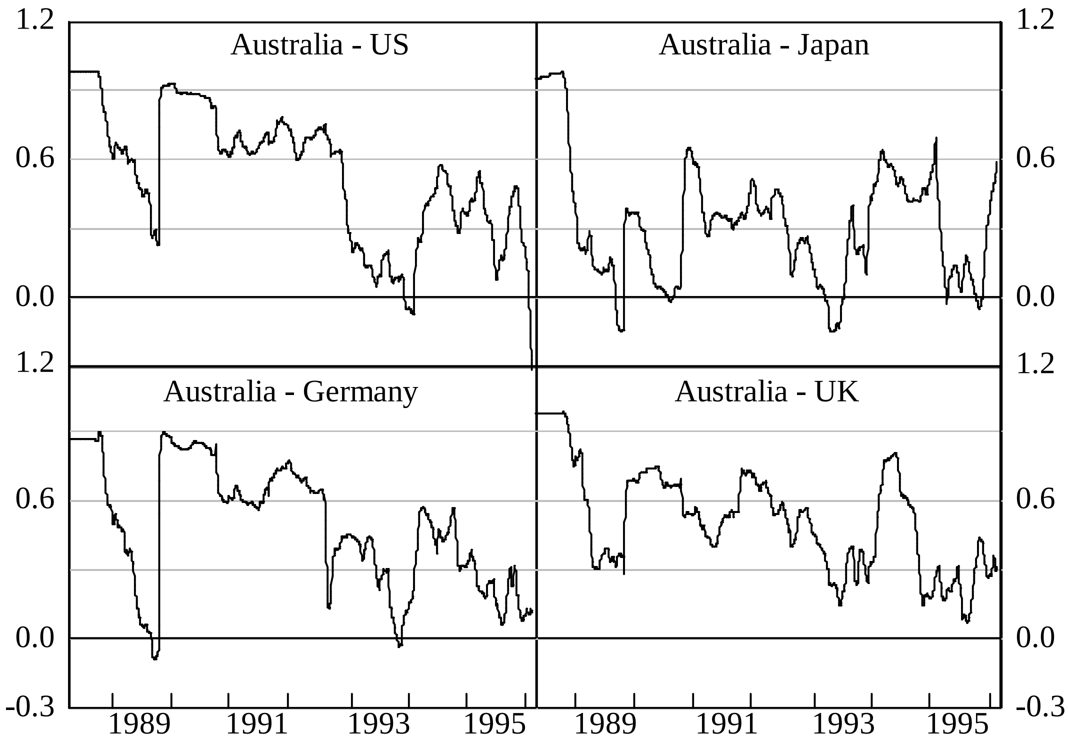
- Japan and Germany had the most turbulent markets. Their average volatility was distinctly higher than the other countries. This is in contrast to the bond market, where they had the lowest volatility. In Japan, the end of the asset boom triggered large falls in the Nikkei during the 1990s, causing high volatility. Similarly the German stock market suffered large falls, and hence high volatility, during 1990 and 1991.

On the basis of the foregoing, it is possible to divide the countries into two groups. The first group, comprising Australia, the US and the UK, is characterised by relatively low and stable volatility (average around 0.8 per cent), a small number of surges and very high volatility during the 1987 episode. The second group, Japan and Germany, features higher average volatility (1 per cent or more) but a more subdued volatility response to the 1987 stock-market crash.

2.2.2 Correlations and market linkages

Rolling correlations of share-market volatility are shown in Figure 5. The correlations, while initially very high, (reflecting the 1987 stock-market crash), decline over the sample period.[7] The falling correlations suggest that the Australian share market became less sensitive to other markets' volatility over the sample period.

Figure 5: Share-Market Volatility – Rolling Correlations

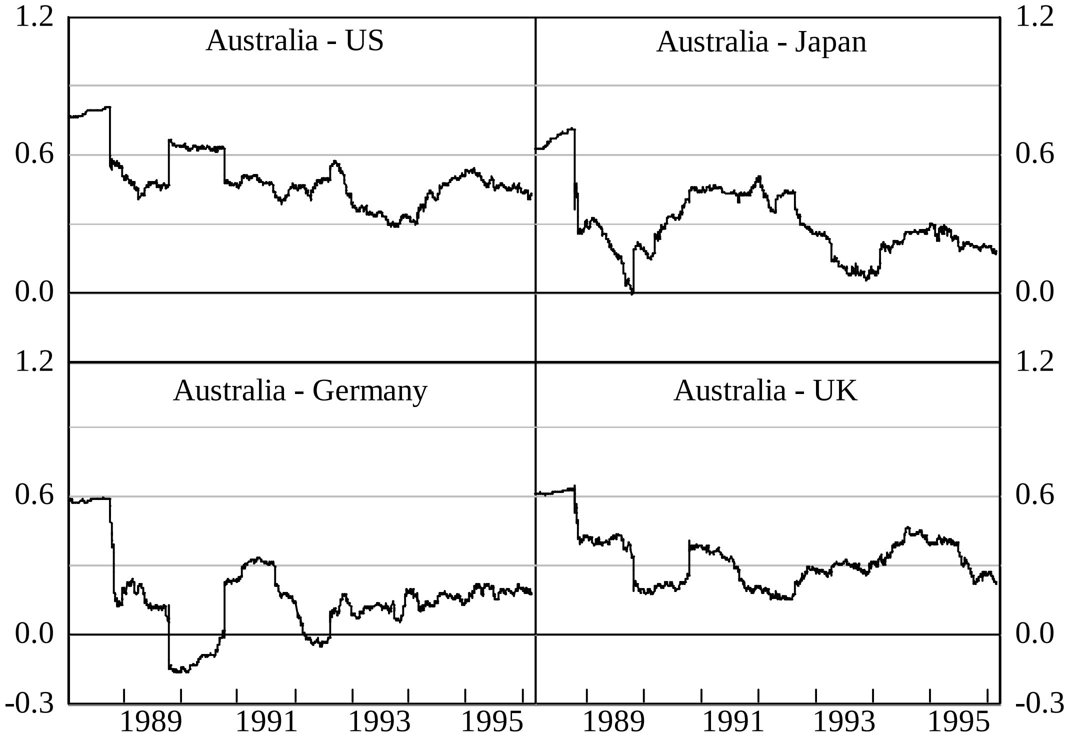


Rolling correlations of daily percentage changes in Australian and foreign share price indices are shown in Figure 6. The main observation that can be made from the charts in Figure 6 is that for the Australian share market, its relationship with daily movements in the US share price is consistently stronger than it is with the other equity markets. The Australia-US correlation is not only consistently higher over the entire sample period, but also displays considerably less variation, than the other pairings.

---

7 Again Japan is the exception, with its correlation with Australia, after falling in the late 1980s, showing no trend in the 1990s.

Figure 6: Rolling Correlations of Daily Percentage Changes in Share Market Indices



2.3 Foreign Exchange Market[8]

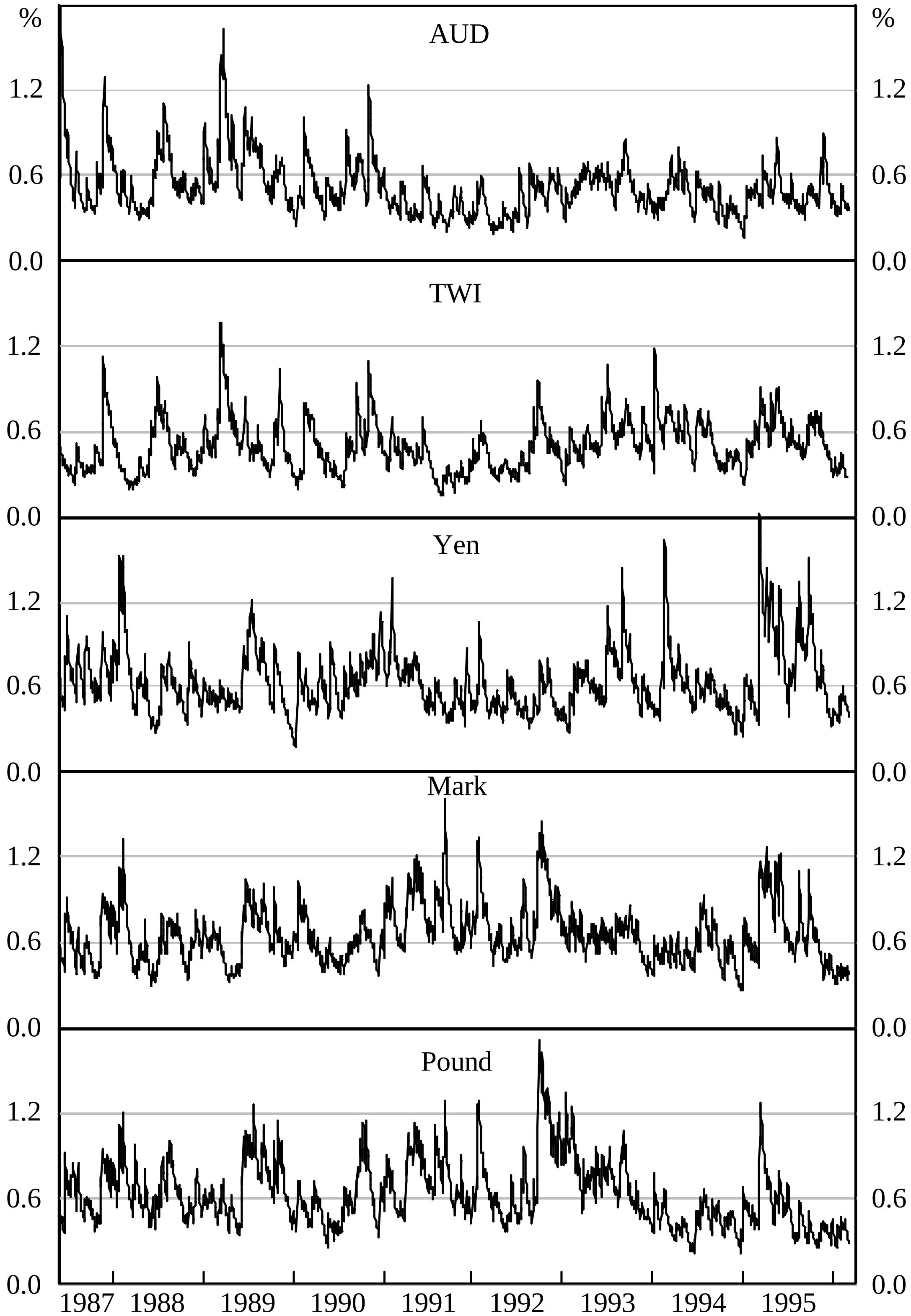
2.3.1 Volatility

Table 3 contains summary statistics of volatility in the foreign exchange market and Figure 7 plots the volatility series. From inspection of Figure 7, it appears that volatility does not show a consistent trend across the various exchange rates. It does appear that the USD/AUD had a negative trend and the JPY/USD a positive one. Simple regressions partially confirm these impressions. The volatility of the USD/AUD and the GBP/USD exchange rates have negative time trends, while the TWI has a positive trend. The yen and German mark do not

---

8 The exchange rates considered here are: USD per AUD, JPY per USD; DEM per USD; and GBP per USD. With the exception of the USD/AUD, each exchange rate is expressed as the foreign currency price of one US dollar: the USD/AUD is the US dollar price of one Australian dollar. The observations are the rates quoted at 15.00 New York (Eastern) Time by Bankers Trust. As such, the time zone differences problem does not apply to exchange rates and there is no need to lag observations from some markets when calculating correlations.

Figure 7: Exchange Rate Volatility



have significant trends. For the USD/AUD from 1991 onwards, volatility was lower with fewer and less dramatic spikes. The GBP/USD experienced some high volatility in the early 1990s, culminating in September 1992 with the ERM crisis. Thereafter, it fell to its lowest volatility of the period. As might be expected, the TWI had more consistent volatility than the USD/AUD. While it had fewer large spikes of volatility in the second half, it also experienced higher troughs, giving it a positive trend.

Table 3: Exchange Rate Volatility (Feb 1987-Feb 1996)

Daily percentage changes

	USD/AUD exchange rate	TWI exchange rate	JPY/USD exchange rate	DEM/USD exchange rate	GBP/USD exchange rate
Maximum	1.77	1.36	1.80	1.56	1.70
Highest 5%	0.86	0.80	1.08	1.05	1.05
Average	0.51	0.50	0.63	0.65	0.63
Standard deviation	0.192	0.178	0.225	0.199	0.227
Median	0.48	0.47	0.59	0.67	0.59
Lowest 5%	0.27	0.25	0.36	0.38	0.34
Minimum	0.16	0.14	0.17	0.26	0.21
Tension coefficient (i)	3.13	3.15	3.02	2.77	3.11
Tension coefficient (ii)	5.52	5.13	5.09	3.80	4.74

Note: The tension coefficient (i) is defined as the ratio of a volatility series' 95-percentile value to its five-percentile value. Tension coefficient (ii) is defined in a similar manner, except that it relates to the ratio of the 99-percentile value to the one-percentile value.

The foreign exchange markets had low levels of volatility in terms of percentage changes compared to share markets.[9] The TWI, as a composite exchange rate, may be expected to have lower average volatility, but the USD/AUD was also distinctly more subdued than the other bilateral rates. The DEM/USD had the highest average volatility, but there is little difference between the average volatilities of the German mark, yen and pound sterling exchange rates.

[9] From Table 1 it would seem that the bond market had easily the lowest volatility. However, volatility in Table 1 is calculated using daily basis point changes. If daily percentage changes are used, bond-market volatility is approximately equal to that of the share market.

The TWI had the least variation in its volatility. Of more interest is the high variation about the mean of the yen and pound sterling volatilities. The comparatively low variability of the AUD and TWI volatilities is not, however, reflected in the exchange rates' tension coefficients. This is because while the AUD and TWI had fewer surges of volatility, the size of their surges were just as great as those of the other exchange rates. When combined with their lower troughs, this gives the AUD and the TWI the highest tension coefficients.

Unsurprisingly, the GBP/USD and DEM/USD exchange rates have quite similar volatility profiles, indicating closely aligned currencies. The JPY/USD shares several episodes of high volatility with these two currencies (early 1988, mid 1989 and early 1995) which the USD/AUD did not experience. This, combined with the low average volatility of the USD/AUD, suggests that the Australian dollar may be connected relatively closely to the US dollar.

3. Cross-Country Linkages

In this section some econometric analysis is undertaken in order to investigate more rigorously the role of international factors in driving changes in Australia's key financial markets. We assess the extent to which developments in foreign bond and equity markets influence the size and direction of changes in the respective Australian counterpart markets.[10] The linkage between daily changes in Australian and foreign bond yields is examined first. This is followed by an investigation into the responsiveness of daily changes in Australian share prices to developments in major overseas stock markets.

10 Some literature on 'spillover' and 'contagion' effects already exists. Recent contributions focusing on spillover effects in equity markets include: Bertero and Mayer (1990), Eun and Shim (1989), Hamao, Masulis, and Ng (1990), King and Wadwhani (1990), Koch and Koch (1991), Lin and Ito (1994), Roll (1989), and von Furstenburg and Jeon (1989). With the exception of Borio and McCauley (1996) and some of the papers in Bank for International Settlements (1996), studies focussing on bond-market spillovers are comparatively few in number.

3.1 Bond Markets

3.1.1 The Australian and US bond-market linkage

The examination undertaken in Section 2.1, was suggestive of an increased co-movement in the daily changes of Australian and US bond yields.

In order to further investigate this relationship, we estimate the following two simple equations:

$$x_t^{AUS} = a_0 + bx_{t-1}^{AUS} + e_t \tag{1}$$

$$x_t^{AUS} = a_0 + bx_{t-1}^{AUS} + gx_{t-1}^{US} + e_t \tag{2}$$

where: x_t^m represent the daily 'close-to-close' basis point change in country *m*'s long bond yield.[11]

In order to obtain estimates of the dynamic profile of the US-Australia bond-market linkage, we run rolling regressions of equations (1) and (2) using daily observations from February 1987 to February 1996.[12] In these, and all subsequent rolling regressions we employ a 120-day (six-month) moving window, generating over 2,220 sets of estimates for each equation.

The results from these estimations are summarised in Figure 8. The increasing importance of the US bond market, in influencing the size and direction of

---

[11] The problem of data synchronisation, due to the presence of time zone differences between the Australian and US markets, needs to be properly addressed. Since the *United States day t* occurs *after* the *Australian day t*, equation (2) is specified so that it is x_{t-1}^{US} – the *US day t-1* basis point change in US long bonds – which appears as the regressor in (2) rather than x_t^{US}.

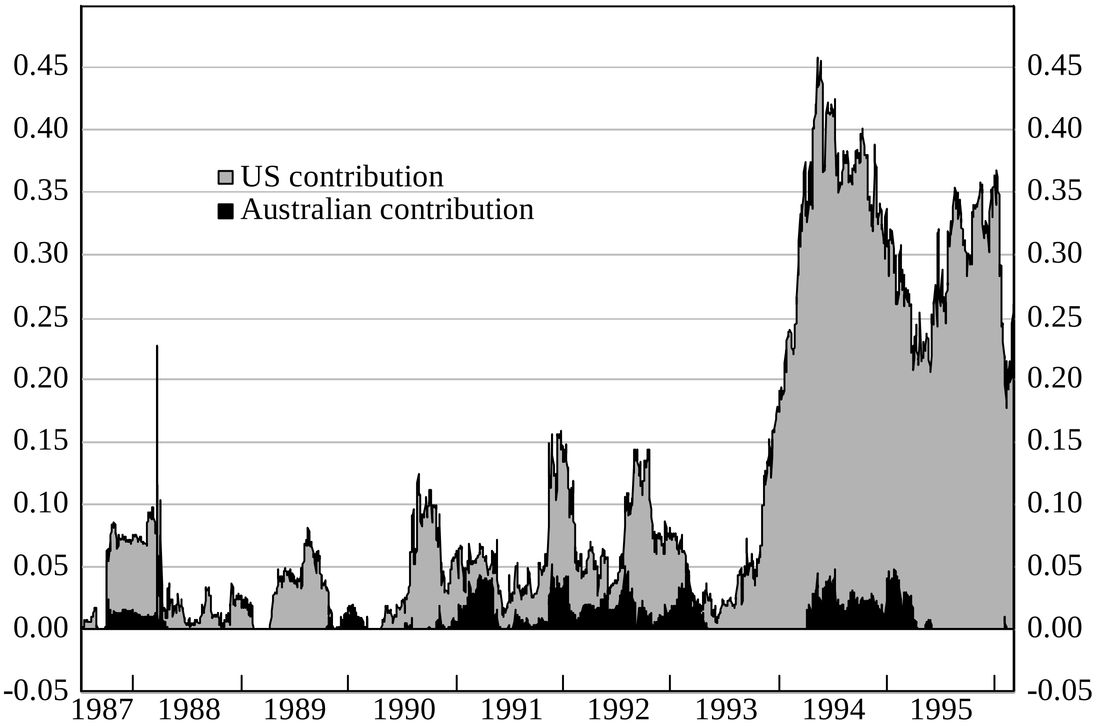
[12] Standard OLS estimation will generate fixed parameter estimates, representing average values over the entire estimation period. Such a procedure will thus effectively mask any temporal changes that may occur in the relationship between the dependant and explanatory variables. Rolling regressions, on the other hand, estimated over such a sliding six-month window, will provide time-varying estimates of the relevant coefficients. This will highlight, as well as identify the timing of, any potential change that may occur in the relationship between the US and Australian bond markets.

movements in the Australian bond market from late 1993 onwards, is clearly illustrated by Figure 8.

Figure 8 plots the adjusted coefficients of determination, $\bar{R}^2$s from rolling regressions (1) and (2) over the full sample. The darker shaded area, termed ‘Australian Contribution’, is simply the $\bar{R}^2$ from regression (1), ie $(\bar{R}^2_{(1)})_t$. The lightly shaded area, denoted by ‘US Contribution’, is the $\bar{R}^2$ from equation (2) less the $\bar{R}^2$ from equation (1), ie $(\bar{R}^2_{(2)} - \bar{R}^2_{(1)})_t$. This represents the additional explanatory power provided by the inclusion of x^{US}_{t-1} as a regressor in the equation specification, and can be interpreted as reflecting the US market's *spillover effect* on the Australian bond market.

Figure 8: Australian Bond Market

Daily basis point changes



The most striking feature of Figure 8 is the rapid and substantial increase in the explanatory power of equation (2) since late 1993. A pronounced and sustained spillover effect from the US to Australian bond markets appears to exist in the last two years of the sample.

Specifically, Figure 8 reveals the following.

- The specification described by equation (1) provides little explanatory power over the entire sample period; the previous day's basis point change in Australian bond yields generally cannot account for any of the observed variation in current daily basis point changes in Australian yields.

- Inclusion of x_{t-1}^{US} as an additional regressor leads to an increase in explanatory power, although this improvement in goodness-of-fit displays considerable variation over the period. Overnight (Australian time) US bond-market movements contribute to explaining, at most, an additional 10 per cent of daily basis point changes in Australian bond yields, over the period 1987 to end 1993. This contrasts with the last two years of the sample period, 1994 and 1995, when US bond-market movements sometimes account for an additional 45 per cent of the total variation in observed changes in Australian yields .

The increasing influence of the US bond market is also reflected in estimates of coefficient γ on the regressor x_{t-1}^{US} in equation (2), presented in Figure 9. Daily basis point changes in Australian bond yields have clearly increased their sensitivity to overnight changes in the US long bond yield, over the time period considered. Especially noteworthy, is the sudden and apparently permanent increase in this coefficient estimate since 1993. Over the period March 1993 to November 1994 the sensitivity of daily yield changes in the Australian market to daily changes in US bond yields, records more than a ten-fold increase, rising from 0.10 to around 1.

Figure 9: Coefficient Value on US Daily Basis Point Change

3.1.2 The influence of other foreign markets

The question naturally arises as to whether other foreign bond markets also have similar spillover effects on the Australian market. Specifically we examine the relative importance of movements in the Japanese, German and UK bond markets in influencing the size and direction of daily changes in Australian bond yields.

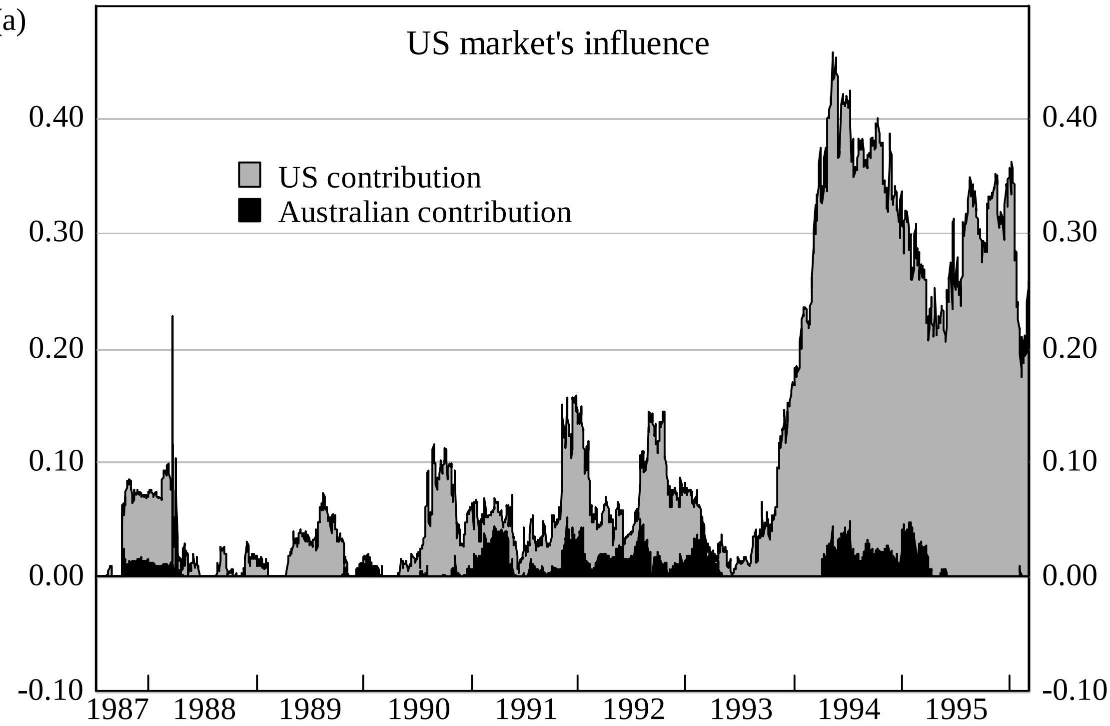
The results from a series of estimations attempting to assess the relative influence of these other key bond markets are depicted in Figure 10. The charts in Figure 10 summarise rolling regression estimates of equations (1) to (5) displayed in Box 1 below:[13]

[13] Data synchronisation, due to the presence of time-zone differences, dictates that the daily basis point change in German and UK bond yields along with that for the US, enter as a 1-day lagged regressor in the equations (ie indexed by *t-1*). Daily basis point changes in Japanese bond yields, however, enter as a contemporaneous (date *t*) regressor.

Figure 10: Influence of Foreign Bond Markets

Daily basis point changes

(a)



(b)

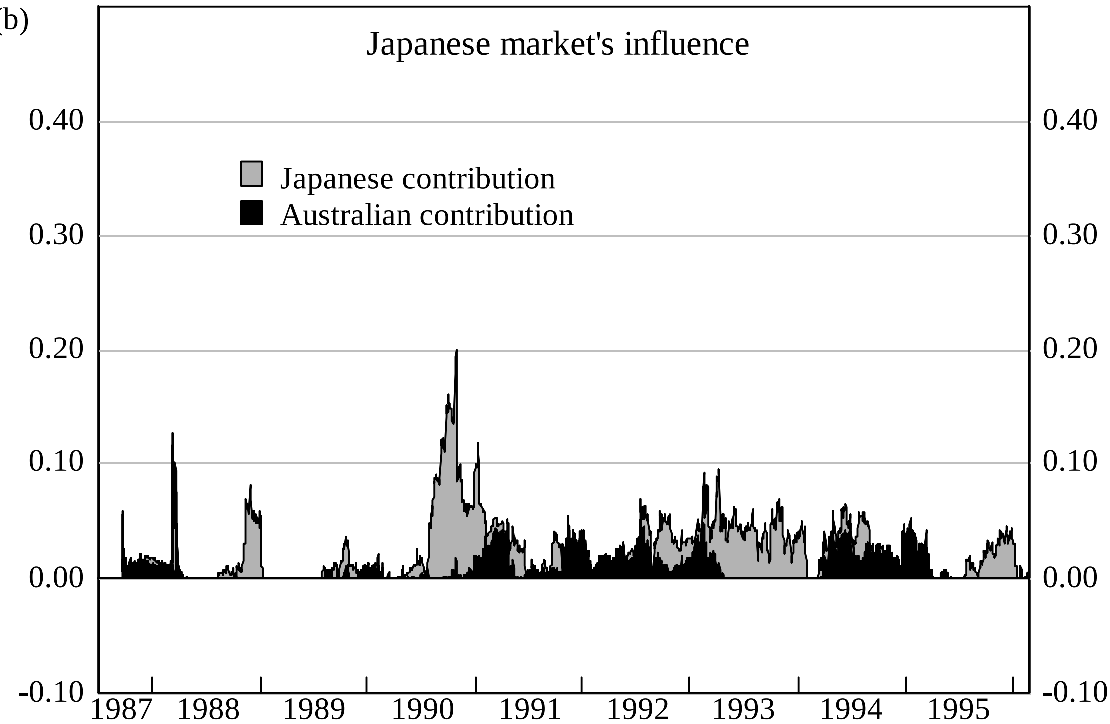
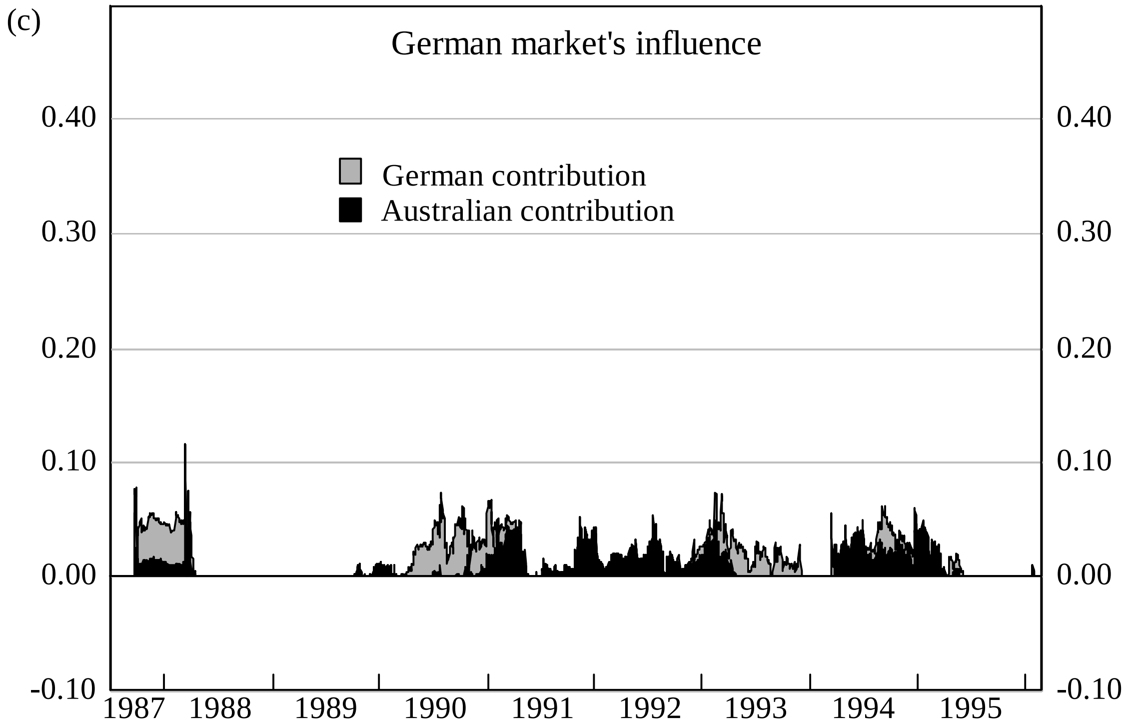
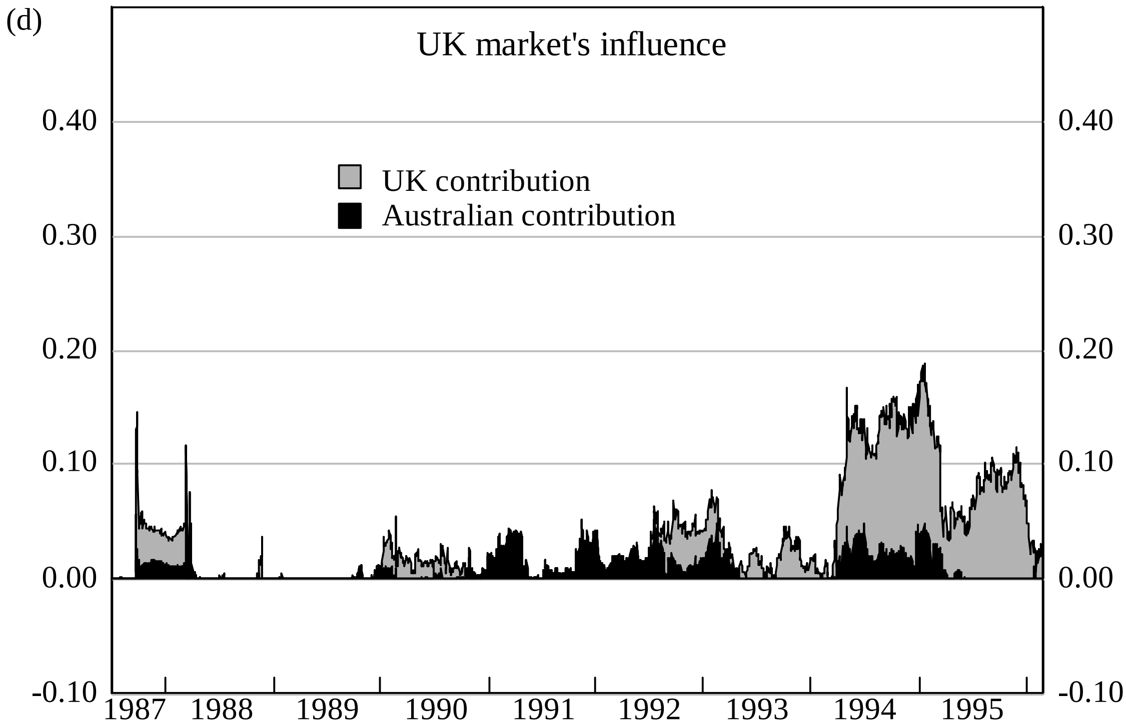


Figure 10: Influence of Foreign Bond Markets (Cont.)
Daily basis point changes





Box 1: The Relative Influence of Foreign Bond Markets

$$x_t^{AUS} = a_0 + bx_{t-1}^{AUS} + e_t \qquad (1)$$

$$x_t^{AUS} = a_0 + bx_{t-1}^{AUS} + gx_{t-1}^{US} + e_t \qquad (2)$$

$$x_t^{AUS} = a_0 + bx_{t-1}^{AUS} + gx_t^{JAP} + e_t \qquad (3)$$

$$x_t^{AUS} = a_0 + bx_{t-1}^{AUS} + gx_{t-1}^{GER} + e_t \qquad (4)$$

$$x_t^{AUS} = a_0 + bx_{t-1}^{AUS} + gx_{t-1}^{UK} + e_t \qquad (5)$$

The relative importance of the US, Japanese, German and UK bond markets is measured by the increase in explanatory power resulting from the inclusion of the respective daily yield changes in these markets as an additional regressor to the autoregressive specification given by equation (1). Accordingly, for the charts appearing in Figure 10, we have the following definitions:

Australian Contribution $\equiv \bar{R}^2_{(1)}$; *US Contribution* $\equiv (\bar{R}^2_{(2)} - \bar{R}^2_{(1)})$; *Japanese Contribution* $\equiv (\bar{R}^2_{(3)} - \bar{R}^2_{(1)})$; G*erman Contribution* $\equiv (\bar{R}^2_{(4)} - \bar{R}^2_{(1)})$; *UK Contribution* $\equiv (\bar{R}^2_{(5)} - \bar{R}^2_{(1)})$;

where $\bar{R}^2_{(i)}$ represents the adjusted coefficient of determination from regression *i* in Box 1.

It is apparent from the charts in Figure 10 that the incremental contribution of the Japanese, German and UK bond market movements in explaining the daily basis point changes in Australian bond yields is negligible. The bulk of the increase in explanatory power can be attributable to movements in the US bond market. Spillover effects from the Japanese, German and UK markets, if any, are overwhelmingly dominated by spillover effects from overnight movements in

US bond yields.[14] Additional econometric estimations reveal that the influence of these other foreign bond markets is reduced further when the US bond market's impact is explicitly allowed for in the equation specification.[15]

3.1.3 Overnight and intraday basis-point changes in Australian bond yields

The increasing influence of overnight changes in US bond yields upon the Australia bond market, can be further analysed by decomposing the daily changes in Australian bond yields into its *overnight* and *intraday* movements.

The daily (close-to-close) basis point change in Australian bond yields can be divided into an intraday (open-to-close) yield change and an overnight (close[t-1]-to-open) yield change:

$$x_t^{AUS} \equiv x_t^{AUS(day)} + x_t^{AUS(o'night)}$$

where $x_t^{AUS} \equiv i_t^{AUS(close)} - i_{t-1}^{AUS(close)}$ is the daily basis-point change in yields,

$x_t^{AUS(day)} \equiv i_t^{AUS(close)} - i_t^{AUS(open)}$ is the intraday change in the Australian bond yield,

$x_t^{AUS(o'night)} \equiv i_t^{AUS(open)} - i_{t-1}^{AUS(close)}$ is the overnight change in the Australian yield.

Examining the relative impact of US bond yield changes on these two components of the daily change in Australian yields, provides valuable insights into the informational efficiency of the Australian bond market.

---

[14] Rolling regression estimates and analysis, similar in nature to that outlined in Sections 3.1.1 and 3.1.2, were also undertaken for (i) *weekly basis point changes in bond yields* and (ii) w*eekly averages of daily bond-market volatility*. The results from these estimations were qualitatively similar to those identified for daily basis point changes. Evidence exists of sizeable spillovers from foreign bond markets, with developments in the US bond market being the predominant foreign market influence on the Australian bond market.

[15] We estimate (rolling regression) equations $x_t^{AUS} = a_0 + bx_{t-1}^{AUS} + gx_{t-1}^{US} + e_t$ (a) and $x_t^{AUS} = a_0 + bx_{t-1}^{AUS} + gx_{t-1}^{US} + dx_{t-1}^{Foreign} + e_t$ (b), where the foreign bond markets incremental contribution to explanatory power is defined by *Other Foreign Bond Mkt.'s Contribution* $\equiv (\bar{R}^2_{(b)} - \bar{R}^2_{(a)})$.

If the developments overnight in the US bond market reflect the release of new information which is also pertinent to Australian bond yields, informational efficiency in the Australian market would dictate that this 'news' be fully incorporated in Australian *opening* prices or yields. That is, efficient processing of foreign information requires that such changes in US bond yields influence only the overnight change in Australian yields. Detection of an additional impact upon intraday changes in yields would, however, imply the presence of informational inefficiencies in the Australian bond market. Lagged responses by Australian bond market participants during the Australian trading day, possibly reflecting the effects of an initial over-reaction or under-reaction to the foreign market news, should not arise if the market is informationally efficient .

In order to examine this aspect of the Australian bond market the following sets of rolling regressions are estimated:

$$x_t^{AUS(o'night)} = a_0 + b_3 x_{t-1}^{AUS(o'night)} + e_t \tag{6a}$$

$$x_t^{AUS(o'night)} = a_0 + b_3 x_{t-1}^{AUS(o'night)} + g_2 x_{t-1}^{US} + e_t \tag{6b}$$

$$x_t^{AUS(day)} = a_0 + b_2 x_{t-1}^{AUS(day)} + e_t \tag{7a}$$

$$x_t^{AUS(day)} = a_0 + b_2 x_{t-1}^{AUS(day)} + g_1 x_{t-1}^{US} + e_t \tag{7b}$$

As in the cases above, the regressions employ a 120-day moving window. However the data which are used to construct the intraday and overnight yield changes derive from a different source, and extend only for the period January 1990 to February 1996.[16]

The differential impact of changes in US bond yields upon the overnight and intraday components of the daily change in Australian yields is clearly evident from Figures 11 and 12 below. Figure 11 is derived from regression estimates of

---

[16] Daily opening quotes on Australian bond yields were unavailable from *Datastream*. For regressions (14) and (15) the intraday and overnight yield changes are constructed using Sydney Futures Exchange (SFE) data on opening and closing yields for Australian 10-year bond futures.

equations (6a) and (6b), while Figure 12 summarise the results from rolling regressions (7a) and (7b).

The differences between Figure 11 and Figure 12 are stark. They reveal that developments in the US bond market affect only the overnight component of the daily change in Australian yields, while having an insignificant influence on its intraday movement. Closer inspection of Figure 11, indicates that there have been six-monthly intervals in the period 1990 to 1996, where the daily change in US bond yields explains nearly 75 per cent of the observed variation in the overnight change in Australian yields. In contrast, the US market's contribution to explaining the intraday change in yields over the same period, fluctuates between -1 per cent and 5 per cent (see Figure 12).

Such a pattern, as indicated earlier, is consistent with informational efficiency in the Australian bond market. It also provides an interesting interpretation of the large US spillover effect documented in Figure 8 above. Starting in mid 1993, participants in the Australian bond market have interpreted developments in the US bond market as the release of new information increasingly relevant to the future course of Australian bond yields. However, why US bond yield movements should suddenly become intrinsically very pertinent to Australian yields, or alternatively, why they should suddenly be *perceived* by participants in the Australian bond market, as having greater relevance and importance to Australian bond yield movements, are 7two puzzling questions.

Figure 11: US Market's Impact on OVERNIGHT Basis Point Change in Australian Bond Yields

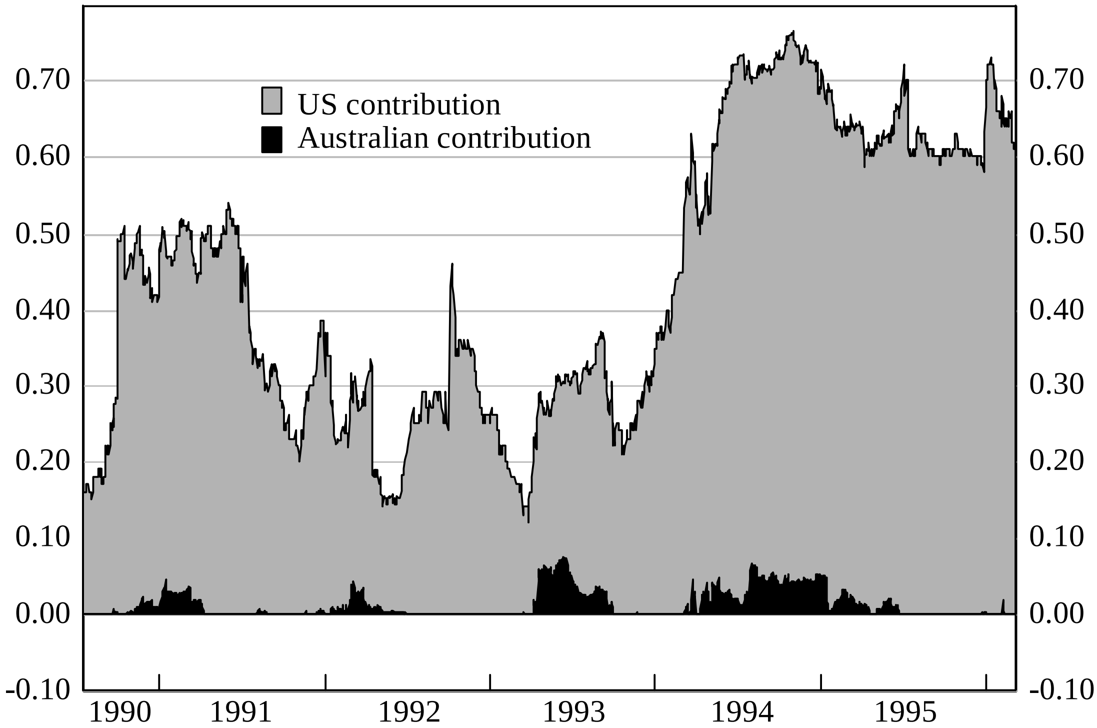
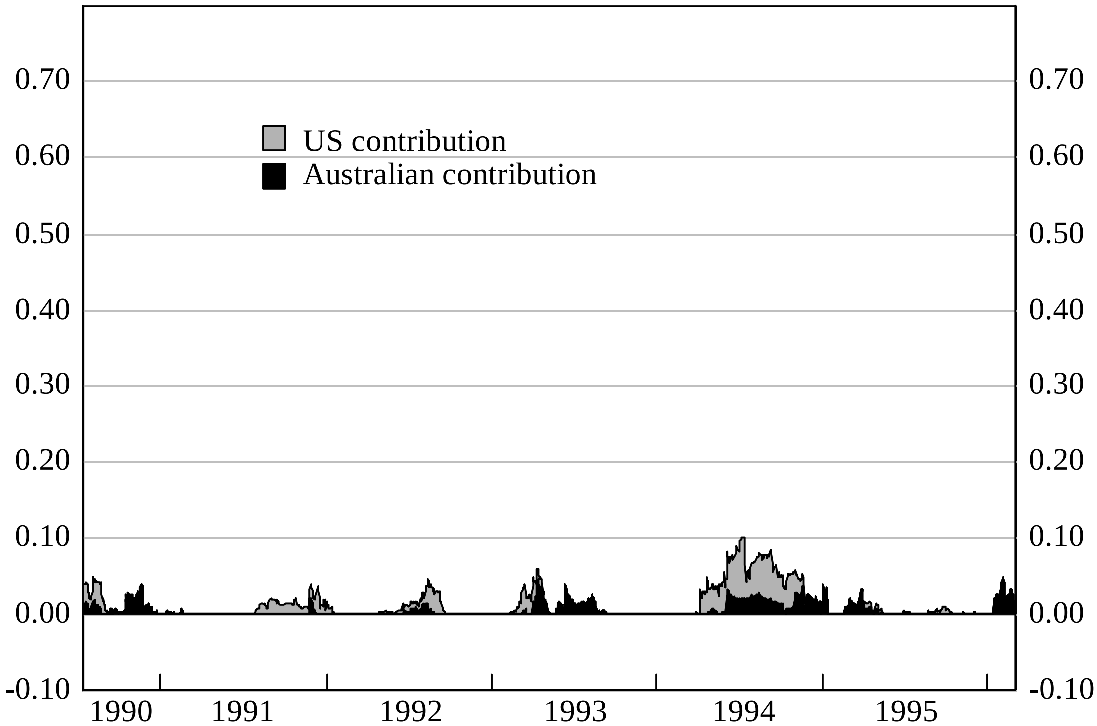


Figure 12: US Market's Impact on INTRADAY Basis Point Change in Australian Bond Yields



3.2 Share Markets

This section reports corresponding results on linkages between international equity markets. Using the same approach as shown in Section 3.1, we examine the relationship between *daily percentage changes* in the respective stock market indices.[17]

3.2.1 The Australian and US share-market linkage

The relationship between daily percentage changes in the Australian and US share market indices is investigated by running rolling regressions of the following two equations over the period February 1987 to February 1996:

$$z_t^{AUS} = a_0 + bz_{t-1}^{AUS} + e_t \tag{8}$$

$$z_t^{AUS} = a_0 + bz_{t-1}^{AUS} + gz_{t-1}^{US} + e_t \tag{9}$$

where: z_t^{AUS} and z_t^{US} represent respectively the daily percentage change in the Australian and US share market indices.

Plots of the time-varying $\bar{R}^2$s from these two estimated equations are contained in Figure 13 below.

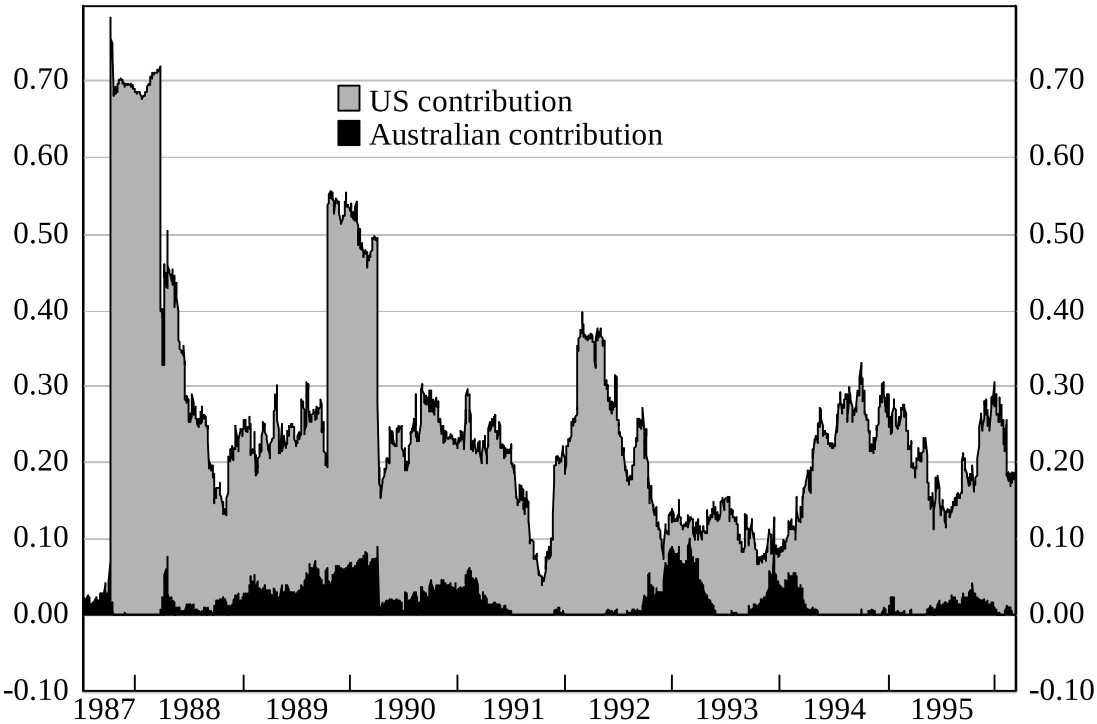
As with the situation for bond markets, developments in the US stock market appear to have a significant impact in determining the size and direction of daily changes in the Australian market. Figure 13 shows that a sizeable proportion of the observed daily percentages changes in the Australian share market index over the sample period can be accounted for by overnight movements in the US market. This is typically around 25 per cent, apart from some exceptional periods.

---

[17] The empirical examination detailed below is also undertaken for *weekly percentage changes* in the share market indices as well as for *weekly averages of daily share-price volatility*. The results from these investigations yielded conclusions qualitatively similar in nature to those found for daily percentage changes in share prices.

Figure 13: Australian Share Market

Daily percentage change



Differences are clearly evident however, when comparing the temporal profiles of the US bond and share markets' spillovers onto their respective counterpart Australian markets. Whereas the spillover from US to Australian bond markets is prominent only in the last two years, 1994 and 1995, the spillover from the US to the Australian stock markets is prevalent in a sizeable way throughout the entire sample period. The incremental contribution to explanatory power of daily changes in US stock prices, while variable, registers at least 20 to 30 per cent for most of the period. Although the US share-market spillover is slight in late 1991 and throughout 1993, it displays a very pronounced impact on Australian share-price movements during episodes of severe market turbulence such as the 1987 stock-market crash, the mini-collapse in 1989, and the bond market 'sell-off' of 1994.

Such a pattern is also reflected in Figure 14, which shows how the Australian share market's responsiveness to daily changes in US share prices (the γ coefficient from equation (9)), varies over time.

Figure 14: Coefficient Value on Daily Percentage Change in US Share Price Index

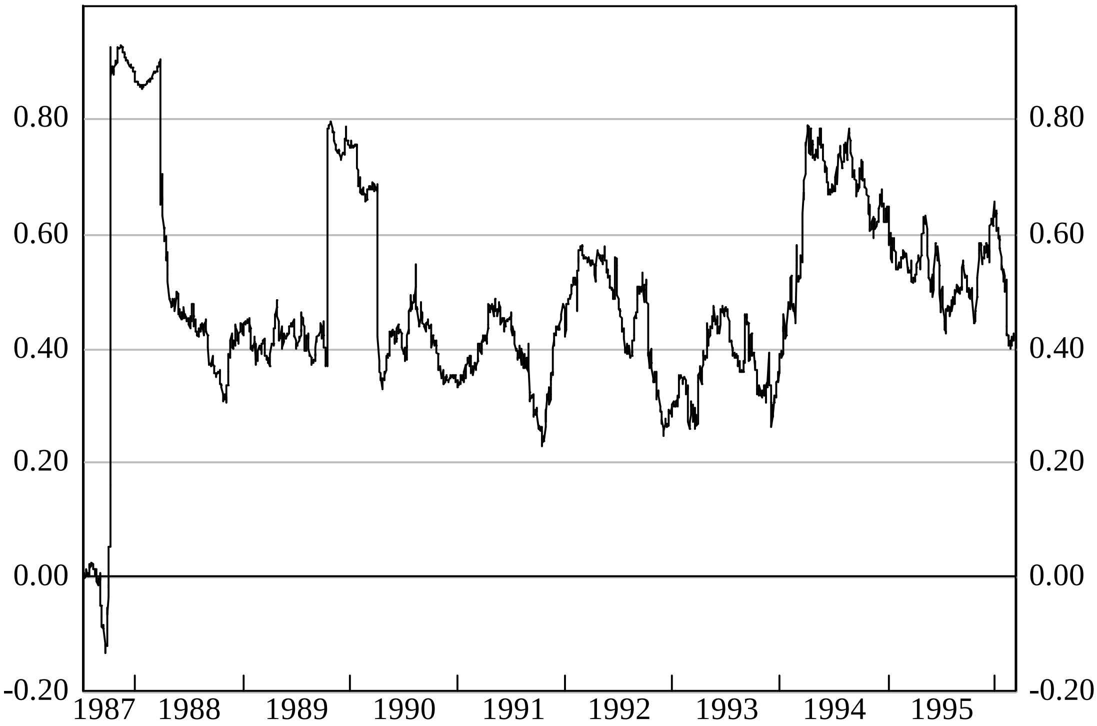


Figure 14 shows that for the most part, the Australian share market's elasticity with respect to developments in the US share market, fluctuates around 0.40. However, in periods of severe financial market turbulence, such as late 1987, late 1989 and early 1994, the Australian share price elasticity to overnight changes in US share prices doubled in size to 0.80. It is also worthwhile observing that Figure 16 does not reveal the presence of an upward trend in the Australian share market's sensitivity to daily changes in US share prices, unlike that documented by Figure 9 for daily changes in bond yields.

3.2.2 The influence of other foreign markets

Results from estimations attempting to gauge the impact of other foreign share markets on the size and direction of daily changes in Australian share prices are summarised by Figure 15. These are derived from rolling regression estimates of the

Figure 15: Influence of Foreign Share Markets

Daily percentage changes

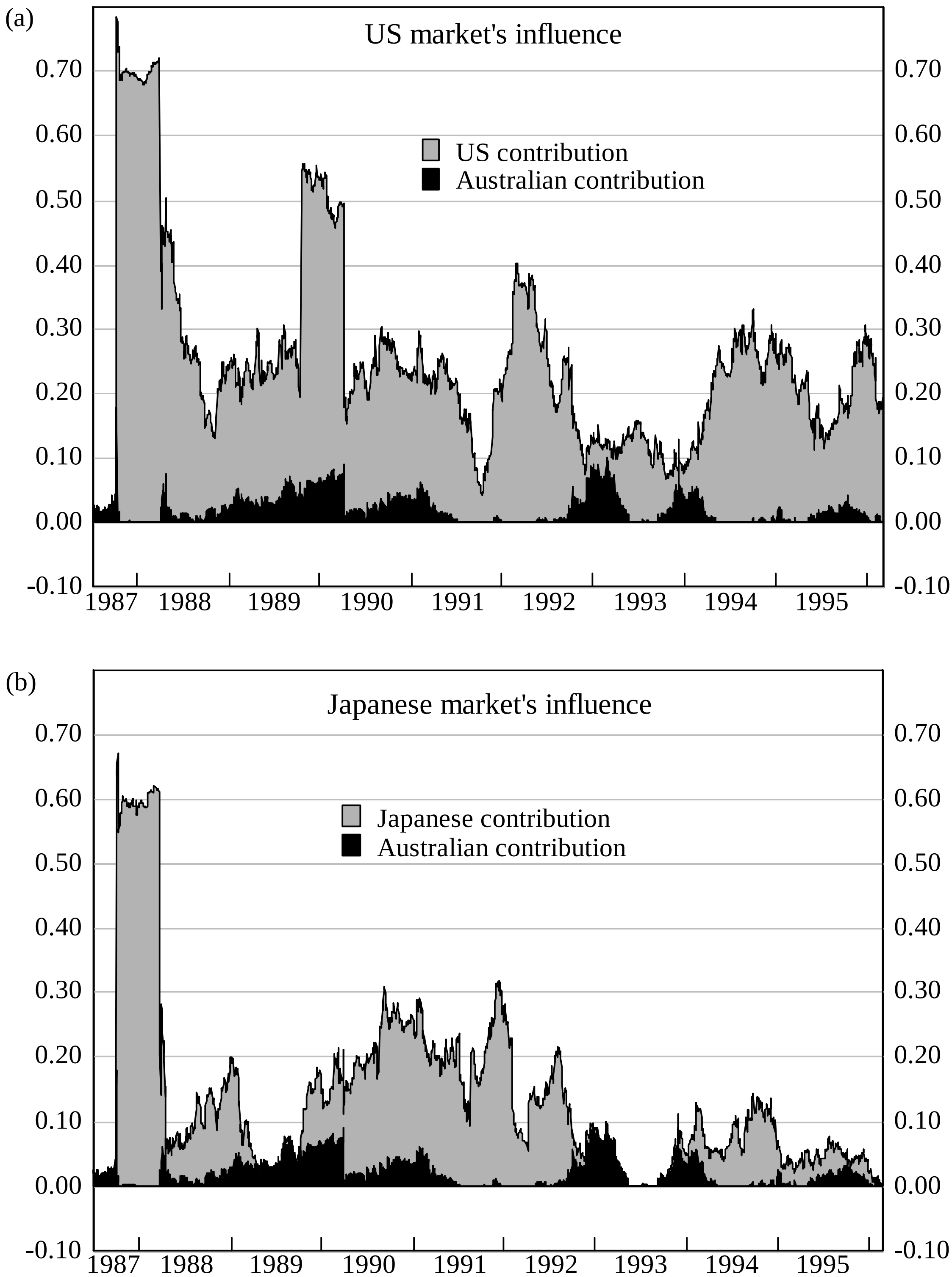
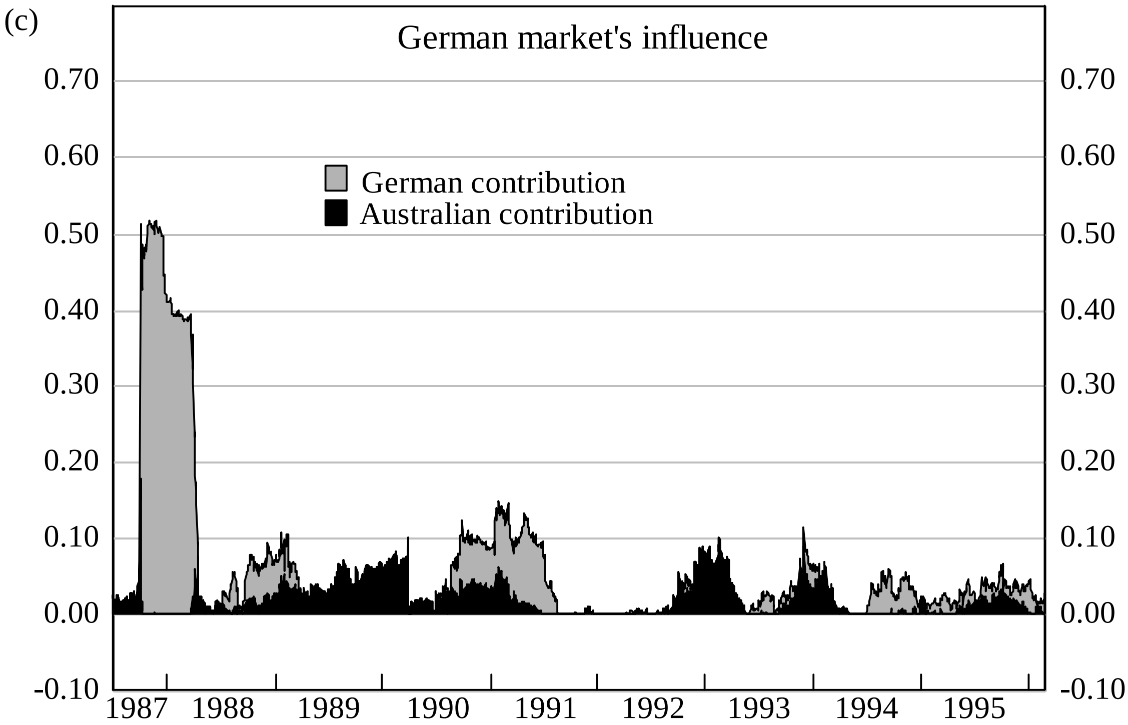
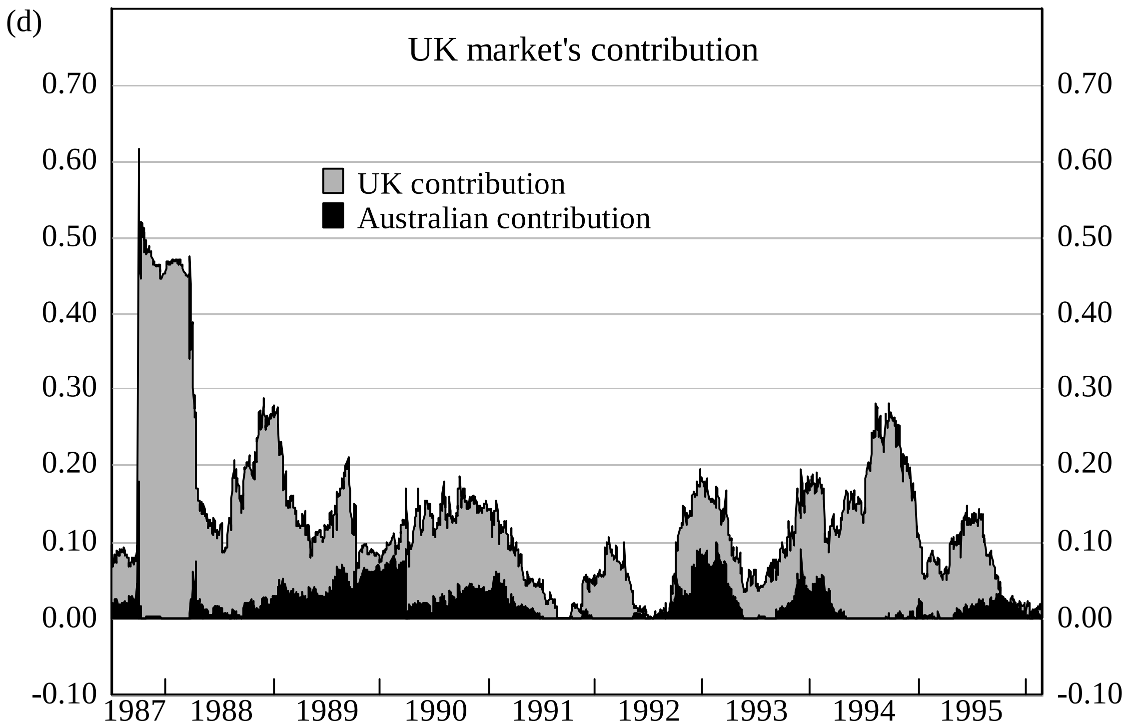


Figure 15: Influence of Foreign Share Markets (Cont.)
Daily percentage changes





equations detailed in Box 2 below, and parallel those which are undertaken for bond markets.[18]

Box 2: The Relative Influence of Foreign Share Markets

$$z_t^{AUS} = a_0 + bz_{t-1}^{AUS} + e_t \tag{8}$$

$$z_t^{AUS} = a_0 + bz_{t-1}^{AUS} + g_{t-1}^{US} + e_t \tag{9}$$

$$z_t^{AUS} = a_0 + bz_{t-1}^{AUS} + g_t^{JAP} + e_t \tag{10}$$

$$z_t^{AUS} = a_0 + bz_{t-1}^{AUS} + g_{t-1}^{GER} + e_t \tag{11}$$

$$z_t^{AUS} = a_0 + bz_{t-1}^{AUS} + g_{t-1}^{UK} + e_t \tag{12}$$

The charts in Figure 15 reveal that the predominant foreign market influence on daily changes in Australian share prices is from the US share market. In contrast to the situation for the bond markets however, the US is not the only foreign market which has an impact on Australian share prices.

Chart (b) and Chart (d) of Figure 15 reveal instances of significant spillovers emanating from foreign share markets other than the US. Two main episodes can be identified. First, the period between mid 1990 and end 1992, when daily changes in Japanese share prices appear to have had a significant influence on Australian share prices, and second, the period between late 1992 and end 1994 when changes in UK share prices provide noticeable additions to explanatory power.

---

18 For the charts in Figure 15, we have the following definitions: *Australian Contribution* $\equiv \bar{R}^2_{(8)}$; *US Contribution* $\equiv (\bar{R}^2_{(9)} - \bar{R}^2_{(8)})$; *Japanese Contribution* $\equiv (\bar{R}^2_{(10)} - \bar{R}^2_{(8)})$; G*erman Contribution* $\equiv (\bar{R}^2_{(11)} - \bar{R}^2_{(8)})$; *UK Contribution* $\equiv (\bar{R}^2_{(12)} - \bar{R}^2_{(8)})$; where $\bar{R}^2_{(i)}$ represents the adjusted coefficient of determination from regression *i* in Box 2.

The above conclusions are reinforced by the charts in Figure 16. These summarise the results from estimation of the equations (13) to (17) detailed in Box 3 below and provide an alternative approach to assessing the relative importance of foreign equity markets. Each chart in Figure 16 provides a measure of a particular foreign market's contribution to explanatory power, over and above that which is provided by the combined contribution of all other foreign markets.[19]f

Box 3: The Relative Influence of Foreign Share Markets

$$z_t^{AUS} = a_0 + bz_{t-1}^{AUS} + g_{t-1}^{US} + d_1 z_t^{JAP} + d_2 z_{t-1}^{GER} + d_3 z_{t-1}^{UK} + e_t \quad (13)$$

$$z_t^{AUS} = a_0 + bz_{t-1}^{AUS} + d_1 z_t^{JAP} + d_2 z_{t-1}^{GER} + d_3 z_{t-1}^{UK} + e_t \quad (14)$$

$$z_t^{AUS} = a_0 + bz_{t-1}^{AUS} + g_{t-1}^{US} + d_2 z_{t-1}^{GER} + d_3 z_{t-1}^{UK} + e_t \quad (15)$$

$$z_t^{AUS} = a_0 + bz_{t-1}^{AUS} + g_{t-1}^{US} + d_1 z_t^{JAP} + d_3 z_{t-1}^{UK} + e_t \quad (16)$$

$$z_t^{AUS} = a_0 + bz_{t-1}^{AUS} + g_{t-1}^{US} + d_1 z_t^{JAP} + d_2 z_{t-1}^{GER} + e_t \quad (17)$$

[19] In Figure 16 Chart (a), we have the following definitions: *US Contribution (a)* $\equiv(\bar{R}^2_{(13)} - \bar{R}^2_{(14)})$ and *All Other Countries Excluding US* $\equiv$ $(\bar{R}^2_{(14)})$. Similarly in Chart (b) we have *Japanese Contribution (a)* $\equiv$ $(\bar{R}^2_{(13)} - \bar{R}^2_{(15)})$ and *All Other Countries Excluding Japan* $\equiv$ $(\bar{R}^2_{(15)})$; in Chart (c) *German Contribution (a)* $\equiv(\bar{R}^2_{(13)} - \bar{R}^2_{(16)})$ and *All Other Countries Excluding Germany* $\equiv$ $(\bar{R}^2_{(16)})$; and in Chart (d) *UK Contribution (a)* $\equiv(\bar{R}^2_{(13)} - \bar{R}^2_{(17)})$ and *All Other Counties Excluding UK* $\equiv(\bar{R}^2_{(17)})$.

Figure 16: Influence of Foreign Share Markets

Daily percentage changes

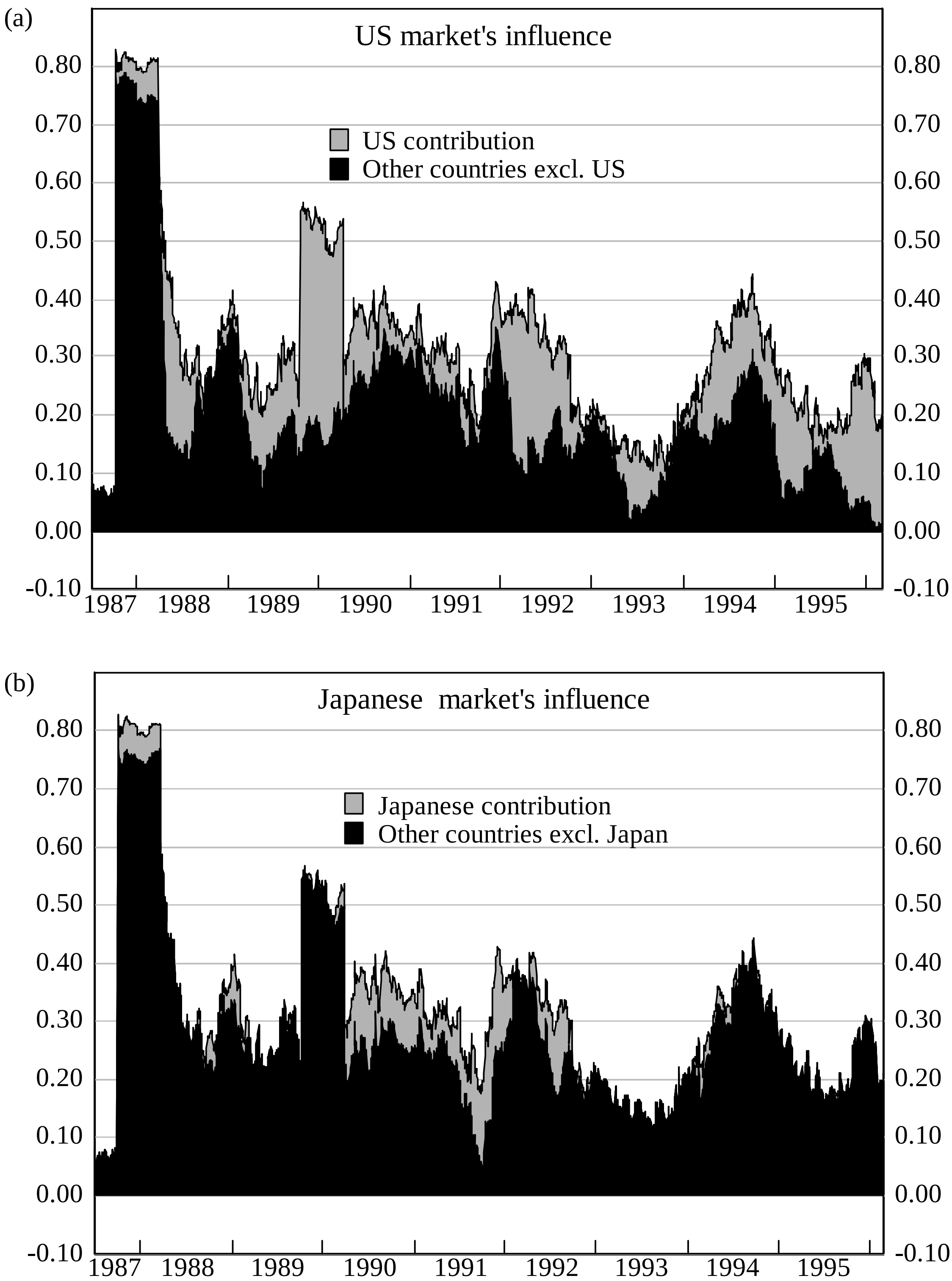
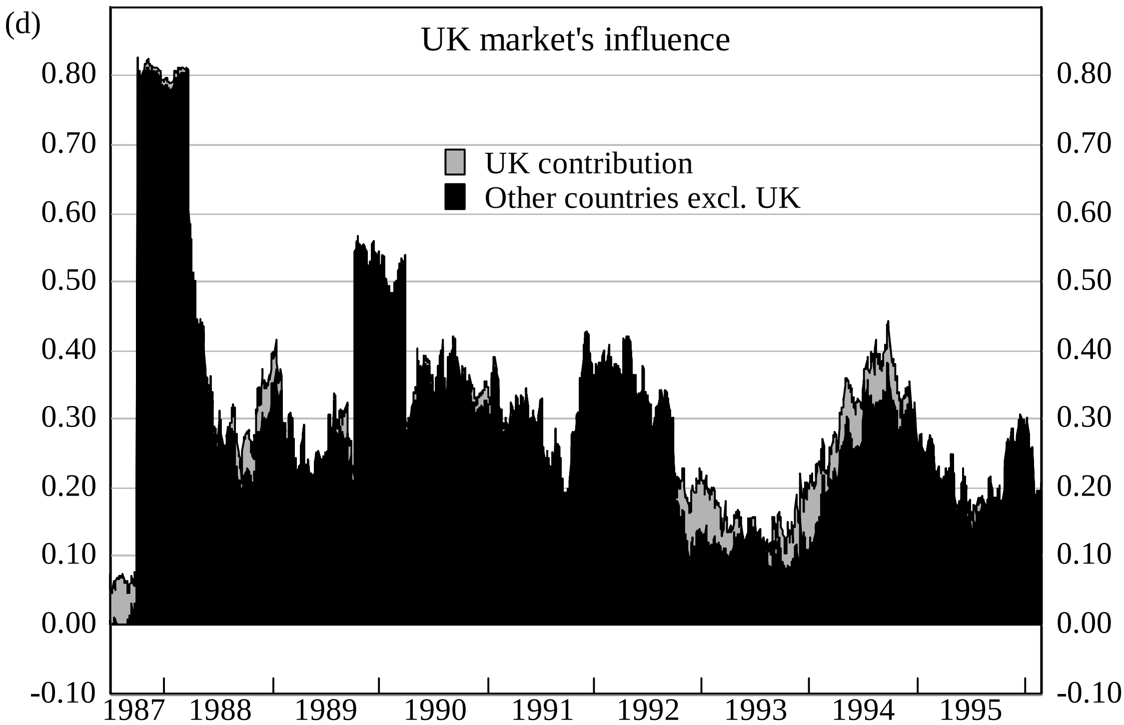


Figure 16: Influence of Foreign Share Markets (Cont.)
Daily percentage changes



4. Australia and the US: Cross-Market Linkages

This section extends the empirical examination undertaken in previous parts of the paper by exploring cross-market as well as cross-country linkages pertaining to Australia's key financial markets.

Given the predominant influence of the US documented in earlier sections, the cross-country link is restricted to the Australia-US pairing. This is supplemented by an explicit consideration of intra-Australian financial market linkages. To illustrate, for the Australian bond market, we examine how changes in Australian bond yields are influenced not only by corresponding movements in US bond yields, but also by changes in US share prices, changes in Australian share prices, and movements in the Australia's TWI exchange rate. A similar examination is undertaken for changes in Australian share prices.

Figure 17 summarises the results from estimations attempting to evaluate the relative importance of cross-market and cross-country influences on daily changes in Australian bond yields. Figure 17 is derived from rolling regressions of equations (4a.1) to (4a.5) detailed in Box 4a below. Once again, these rolling regressions employ a 120-day (6-month) moving window of daily observations over the period February 1987 to February 1996.

In this set of estimations the influence of a particular market on Australian bond yield movements is measured by the reduction in equation (4a.1)'s explanatory power when the regressor representing that market is excluded from the equation specification. To illustrate, equation (4a.3) includes all of the regressors in equation (4a.1)'s specification except that which represents the daily change in US share prices. Accordingly, the US share market's influence or spillover on the Australian bond market is given by the difference in the adjusted coefficients of determination of the unrestricted and restricted regression equations, ie $(\overline{R}^2_{(4a.1)} - \overline{R}^2_{(4a.3)})$.[20]

---

[20] Thus in Figure 17 Chart (a), we have the following definitions: *Contribution of US Share Market* $\equiv(\overline{R}^2_{(4a.1)} - \overline{R}^2_{(4a.3)})$ and *Contribution of Other Markets Excluding US Share Market* $\equiv$ $(\overline{R}^2_{(4a.3)})$. Similarly in Chart (b) we have *Contribution of Australian Share Market* $\equiv$ $(\overline{R}^2_{(4a.1)} - \overline{R}^2_{(4a.4)})$ and *Contribution of Other Markets Excluding Australian Share Market* $\equiv$ $(\overline{R}^2_{(4a.4)})$; in Chart (c) we have *Contribution of US Bond Market* $\equiv(\overline{R}^2_{(4a.1)} - \overline{R}^2_{(4a.2)})$ and

Box 4a: Australian Bond Market

Daily basis point changes

$$x_t^{AUS} = a_0 + b_1 x_{t-1}^{AUS} + b_2 z_t^{AUS} + g_1 x_{t-1}^{US} + g_2 z_{t-1}^{US} + d_1 ex_t + e_t \quad (4a.1)$$

$$x_t^{AUS} = a_0 + b_1 x_{t-1}^{AUS} + b_2 z_t^{AUS} + g_2 z_{t-1}^{US} + d_1 ex_t + e_t \quad (4a.2)$$

$$x_t^{AUS} = a_0 + b_1 x_{t-1}^{AUS} + b_2 z_t^{AUS} + g_1 x_{t-1}^{US} + d_1 ex_t + e_t \quad (4a.3)$$

$$x_t^{AUS} = a_0 + b_1 x_{t-1}^{AUS} + g_1 x_{t-1}^{US} + g_2 z_{t-1}^{US} + d_1 ex_t + e_t \quad (4a.4)$$

$$x_t^{AUS} = a_0 + b_1 x_{t-1}^{AUS} + b_2 z_t^{AUS} + g_1 x_{t-1}^{US} + g_2 z_{t-1}^{US} + e_t \quad (4a.5)$$

where: x_t^m is the daily basis point change in country m's long bond yield, z_t^m is the daily percentage change in country m's share price index, and ex_t is the daily percentage change in Australia's TWI exchange rate.

Figure 17 confirms that overnight (Australian time) changes in US bond yields are the most important influence on Australian bond-yield movements. Its exclusion as a regressor from equation (4a.1) leads to the largest reduction in explanatory power.

The next most important influence, out of the four markets under consideration, appears to be daily movements in Australian share prices. Its incremental contribution to explanatory power is episodic, being prominent only during periods of financial market turbulence such as the 1987 stock-market crash, the 1989 mini-collapse, the period during the Iraqi invasion of Kuwait, and the 1994 bond market 'sell-off'.

Contribution of Other Markets Excluding US Bond Market $\equiv (\bar{R}^2_{(4a.2)})$; and in Chart (d) we have *Contribution of TWI Exchange Rate* $\equiv (\bar{R}^2_{(4a.1)} - \bar{R}^2_{(4a.5)})$ and *Contribution of Other Markets Excluding TWI* $\equiv (\bar{R}^2_{(4a.5)})$.

Figure 17: Australian Bond Market
Cross Market – Cross Country Influences
Daily basis point changes

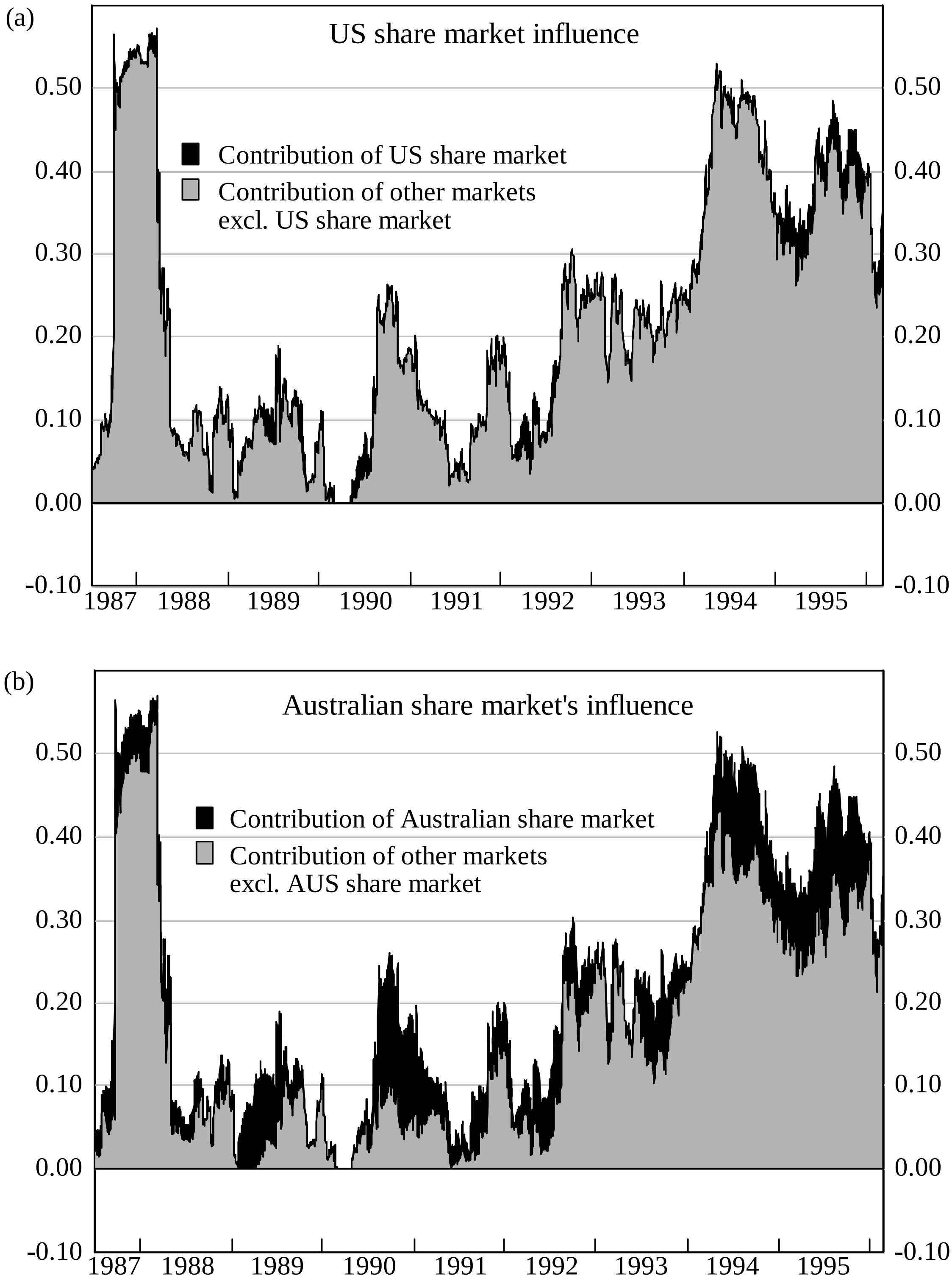
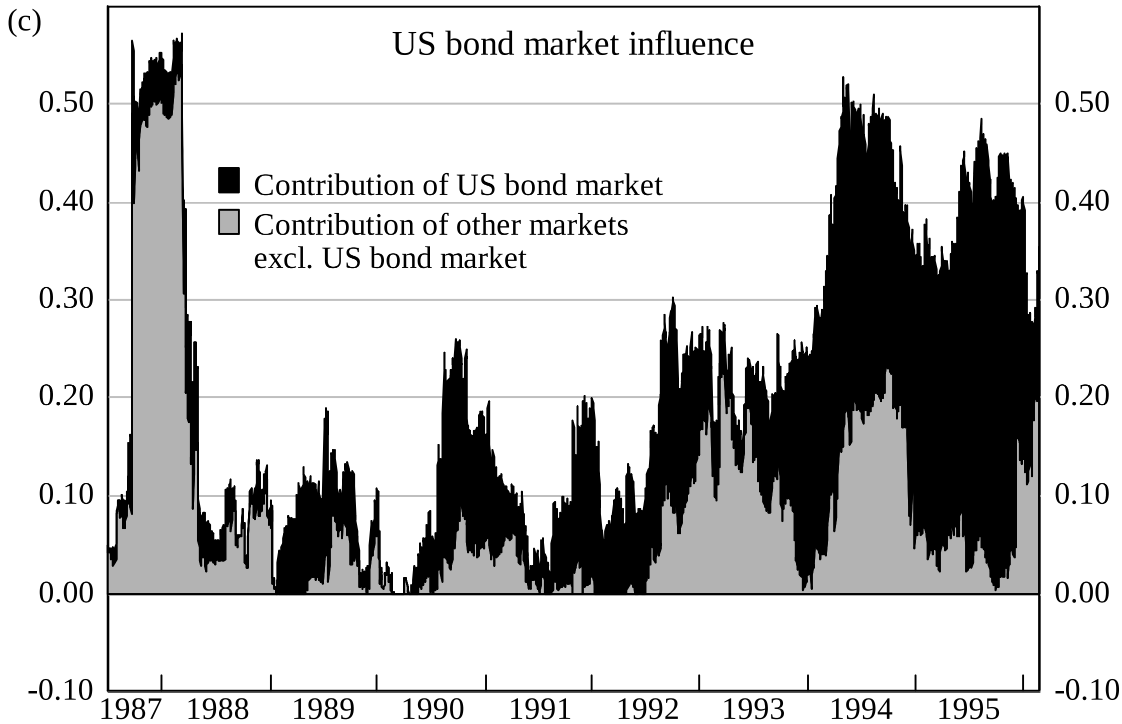
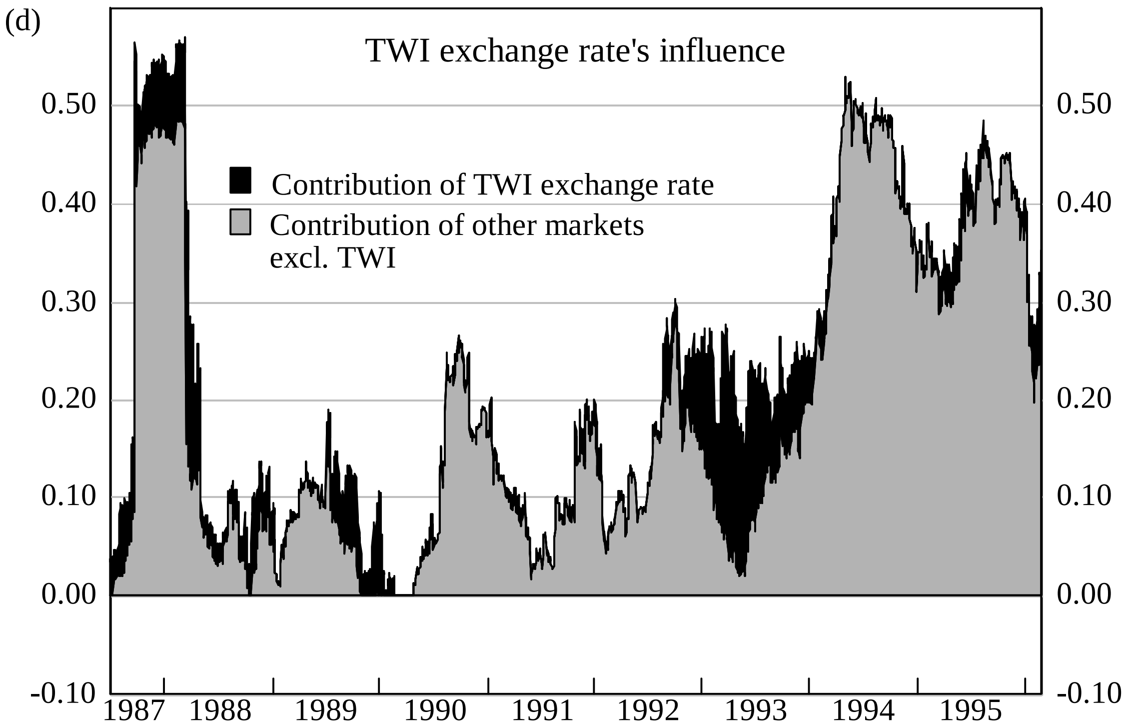


Figure 17: Australian Bond Market
Cross Market – Cross Country Influences (Cont.)
Daily basis point changes





Daily movements in the TWI nominal exchange rate is next. Only in two periods, (i) the 1987 stock-market crash and (ii) throughout most of 1993, do daily percentage changes in the nominal TWI contribute significantly to explanatory power. Daily percentage changes in the US share price index appear to have the least influence on daily changes in Australian bond yields. As can be clearly seen from Figure 17 its exclusion from the regression equation is inconsequential with respect to reductions in explanatory power.

To summarise, for daily yield changes in the Australian bond market, we have the following rankings in descending order of importance: *(i)* US bond market, *(ii)* Australian share market, *(iii)* TWI exchange rate, and *(iv)* US share market.

The results from a similar examination undertaken for daily changes in the Australian share market are depicted in Figure 18, with the equations underlying the rolling regression estimates outlined in Box 4b. [21]

Out of the four markets under consideration, Figure 18 clearly identifies changes in US share prices as the most important influence on daily movements in Australian share prices. As with the Australian bond market, the counterpart US market has the predominant influence. Contemporaneous daily changes in Australian bond yields provide the next largest influence, as measured by its contribution to explanatory power. This is followed by changes in US bond yields, and contemporaneous percentage changes in the TWI exchange rate. The marginal contributions to explanatory power of these last two variables are equally small.

---

[21] Thus in Figure 18 Chart (a), we have the following definitions: *Contribution of US Share Market* $\equiv(\overline{R}^2_{(4b.1)} - \overline{R}^2_{(4b.3)})$ and *Contribution of Other Markets Excluding US Share Market* $\equiv$ $(\overline{R}^2_{(4b.3)})$. Similarly in Chart (b) we have *Contribution of Australian Bond Market* $\equiv$ $(\overline{R}^2_{(4b.1)} - \overline{R}^2_{(4b.4)})$ and *Contribution of Other Markets Excluding Australian Bond Market* $\equiv$ $(\overline{R}^2_{(4b.4)})$; in Chart (c) we have *Contribution of US Bond Market* $\equiv(\overline{R}^2_{(4b.1)} - \overline{R}^2_{(4b.2)})$ and *Contribution of Other Markets Excluding US Bond Market* $\equiv$ $(\overline{R}^2_{(4b.2)})$; and in Chart (d) we have *Contribution of TWI Exchange Rate* $\equiv(\overline{R}^2_{(4b.1)} - \overline{R}^2_{(4b.5)})$ and *Contribution of Other Markets Excluding TWI* $\equiv$ $(\overline{R}^2_{(4b.5)})$.

Box 4b: Australian Share Market (Daily percentage changes)

$$z_t^{AUS} = a_0 + b_1 z_{t-1}^{AUS} + b_2 x_t^{AUS} + g_1 x_{t-1}^{US} + g_2 z_{t-1}^{US} + d_1 ex_t + e_t \qquad (4b.1)$$

$$z_t^{AUS} = a_0 + b_1 z_{t-1}^{AUS} + b_2 x_t^{AUS} + g_2 z_{t-1}^{US} + d_1 ex_t + e_t \qquad (4b.2)$$

$$z_t^{AUS} = a_0 + b_1 z_{t-1}^{AUS} + b_2 x_t^{AUS} + g_1 x_{t-1}^{US} + d_1 ex_t + e_t \qquad (4b.3)$$

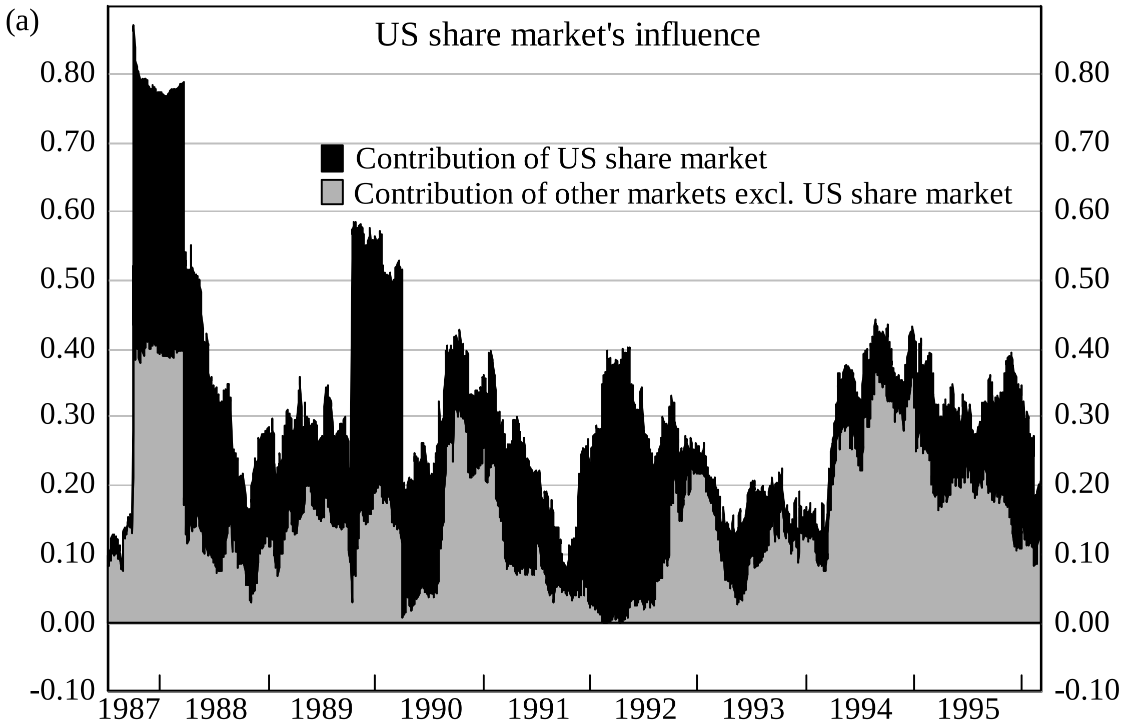
$$z_t^{AUS} = a_0 + b_1 z_{t-1}^{AUS} + g_1 x_{t-1}^{US} + g_2 z_{t-1}^{US} + d_1 ex_t + e_t \qquad (4b.4)$$

$$z_t^{AUS} = a_0 + b_1 z_{t-1}^{AUS} + b_2 x_t^{AUS} + g_1 x_{t-1}^{US} + g_2 z_{t-1}^{US} + e_t \qquad (4b.5)$$

where: x_t^m is the daily basis point change in country m's long bond yield, z_t^m is the daily percentage change in country m's share price index, and ex_t is the daily percentage change in Australia's TWI exchange rate.

The results from Figures 17 and 18 collectively tend to suggest that cross-country spillovers or influences within the same market (eg US share market – Australian share market and US bond market – Australian bond market) are far more pronounced than cross-market/instrument linkages within the same country (eg Australian bond market – Australian share market or Australian bond market – Australian foreign exchange market).

Figure 18: Australian Share Market
Cross Market – Cross Country Influences
Daily percentage changes



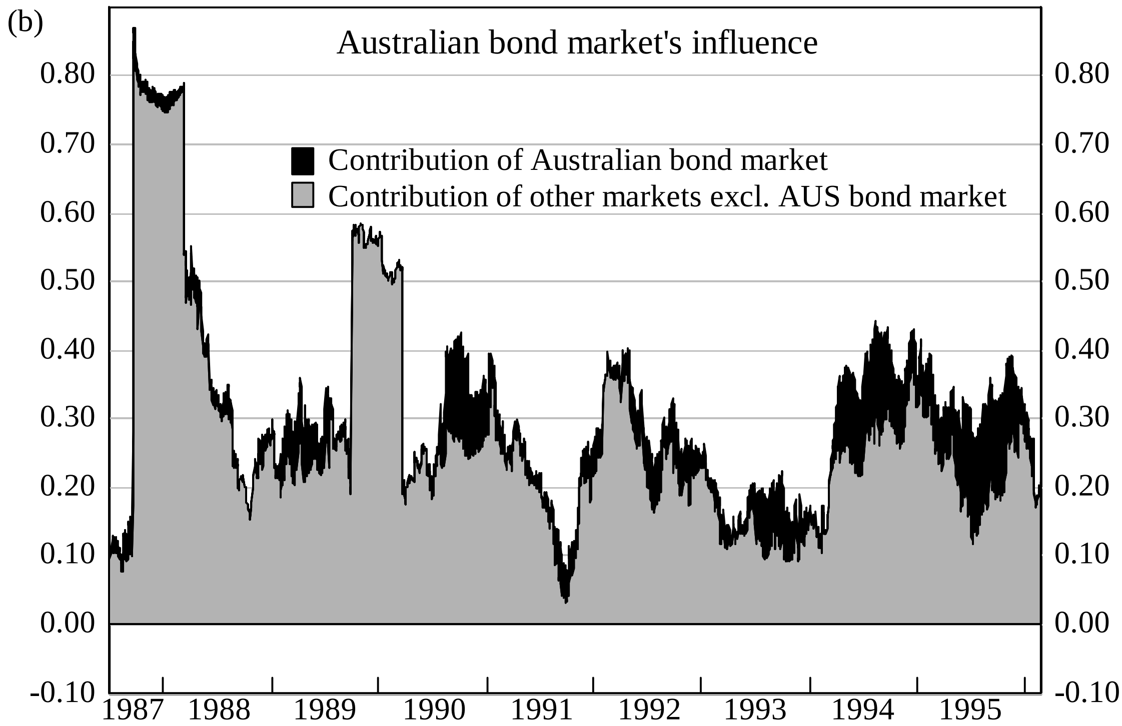
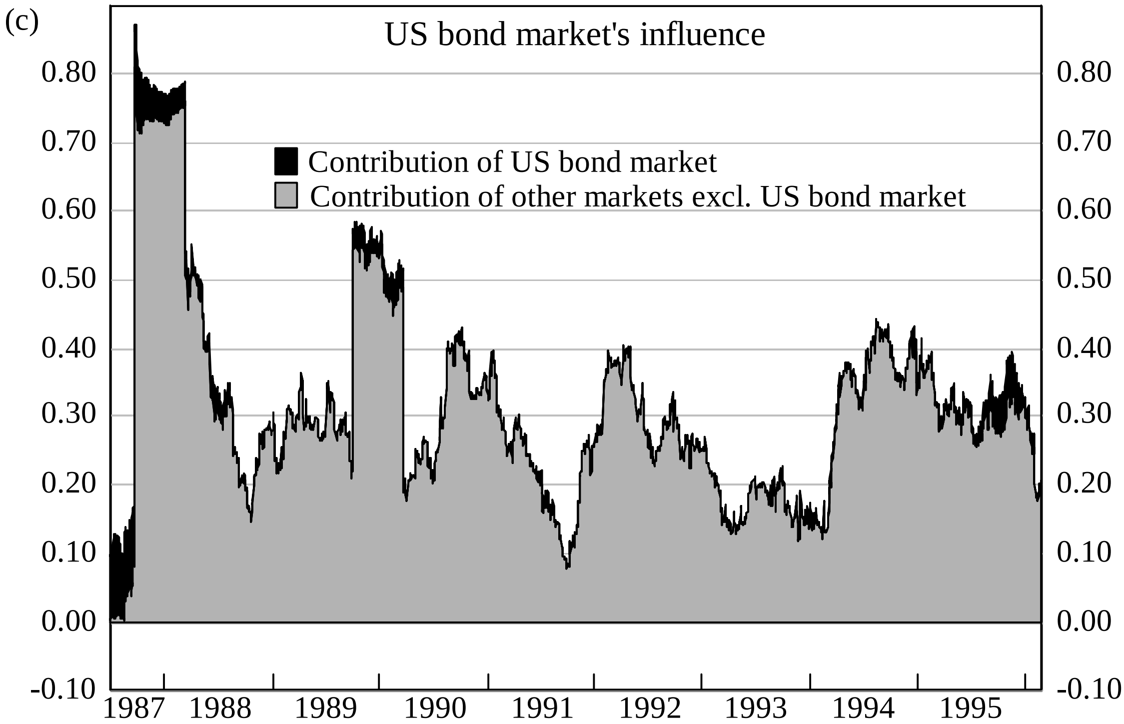
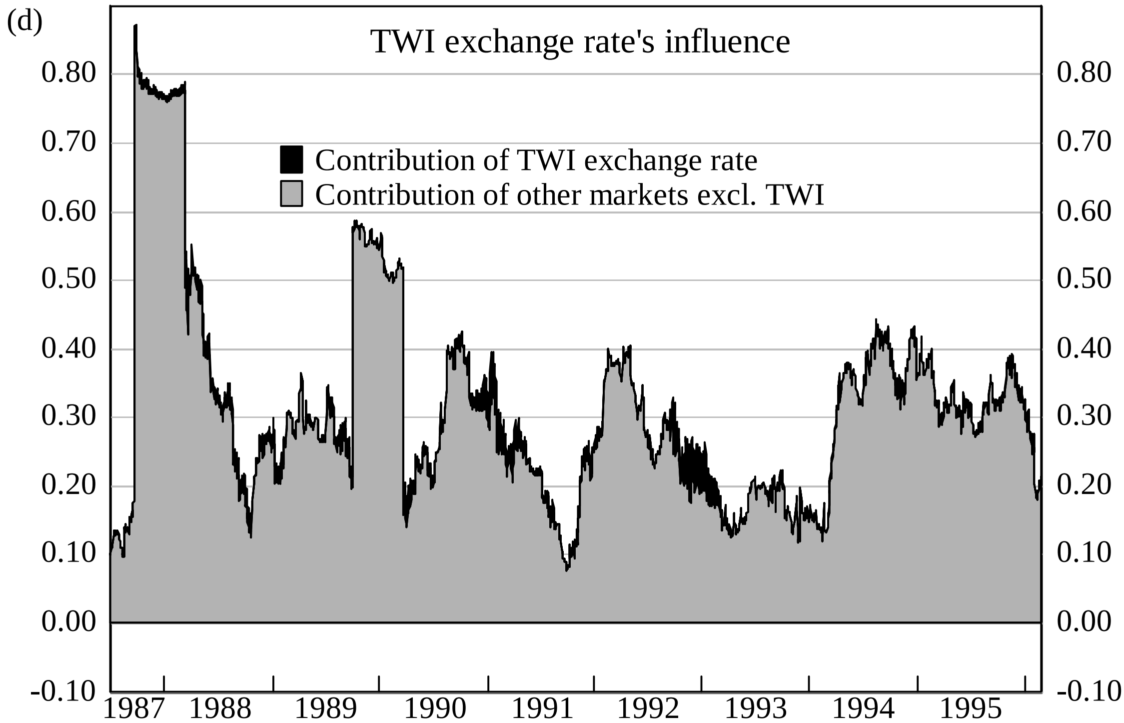


Figure 18: Australian Share Market
Cross Market – Cross Country Influences (Cont.)
Daily percentage changes





5. Other Stylised Facts

This section briefly examines two popular notions regarding volatility and market linkages. The first is that there is an asymmetry to volatility whereby 'bad' news causes more volatility than 'good' news. The second notion is that the strength of relationships between markets varies depending upon the state of the markets. In particular, the volatility in different markets is thought to be more correlated in periods of high volatility and during bear markets.

5.1 Asymmetry in Volatility

A common view held by many financial market observers is that there is an asymmetry or directionality to volatility: unanticipated price falls ('bad news') are believed to engender more volatility than equivalent unanticipated price rises ('good news').[22] This sub-section investigates that issue with respect to the Australian bond and share markets. Two questions are posed: is volatility, on average, higher during bear markets than during bull markets; and are market falls associated with greater volatility than rises of equal magnitude. Both questions receive positive answers. [23]

5.1.1 Is volatility higher during bear markets?

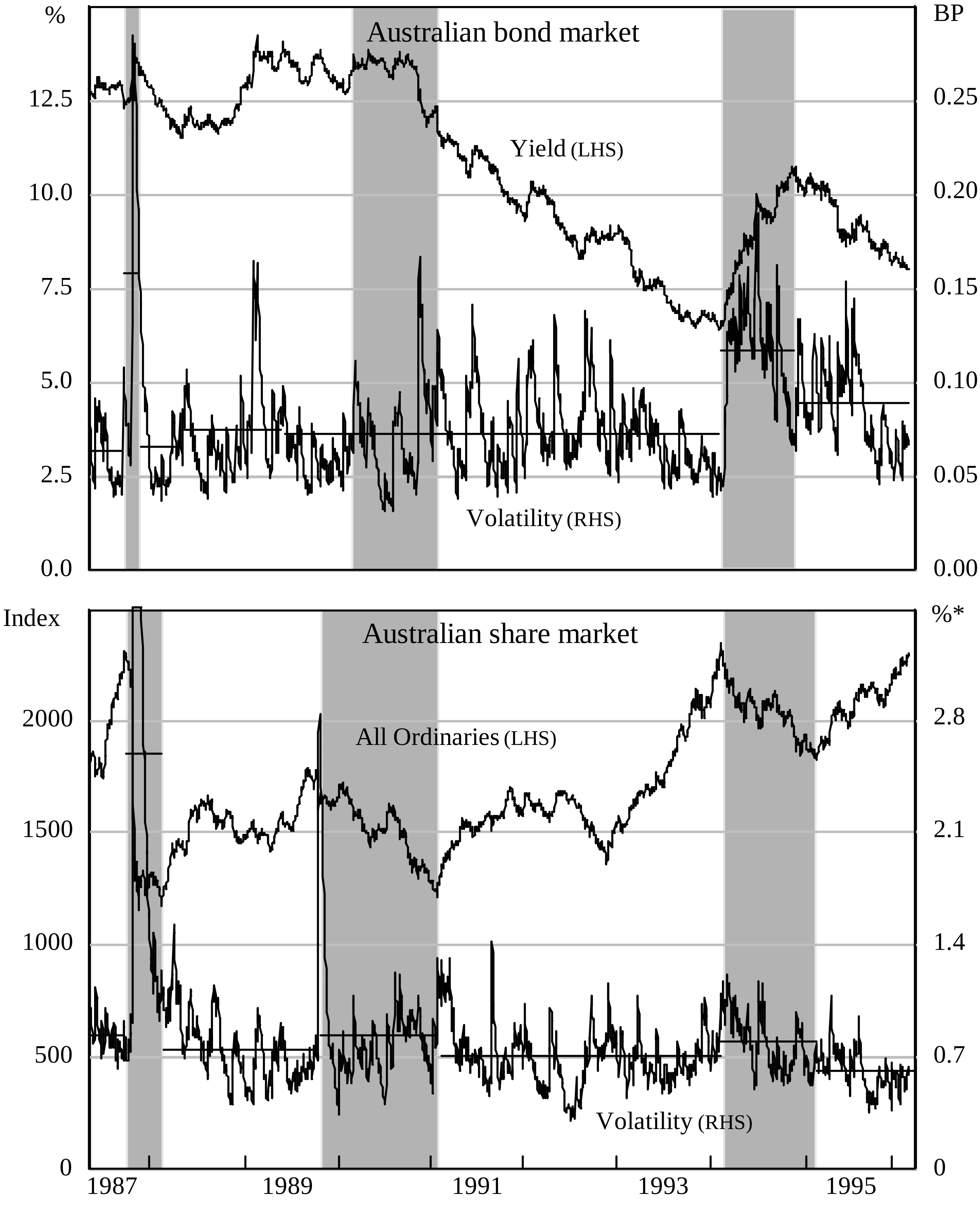
The relationship between volatility and the state of the market is examined by calculating the average volatility of bond and share markets during bull and bear markets. Bear (bull) markets are defined as extended periods of market falls (rises). The state of the market was identified by examining plots of market levels, using daily data, and picking the turning points. The results are shown in Figure 19. The shaded (unshaded) areas represent bear (bull) markets. The horizontal lines show the average volatility during the relevant period. It is apparent from the graphs that in general volatility was higher during bear markets.

---

[22] This feature of directionality or asymmetry in volatility, which is also sometimes referred to in the literature as the 'leverage effect', was first noted by Black (1976).

[23] The approach follows closely that which is adopted by Borio and McCauley (1996), in Annex III pp. 90-98.

Figure 19: Volatility in Bear and Bull Markets



Note: * Scale has been truncated. During the October 1987 stock-market crash, daily Australian share-market volatility reached levels in excess of 9 per cent.

A difference-in-means test was performed where volatility was regressed against a constant and an additive dummy for bear markets. The dummy variable is significant at the 1 per cent level for both bond and share markets: there is a statistically significant difference between average volatility in bull and bear markets.[24] The difference in volatility depending on the state of the market seems to be more marked for shares, indicating that the asymmetry is more pronounced in that market.

Figure 19 also highlights the trends in volatility in each market. In the share market, which has a negative trend to its volatility, each bear (bull) market had lower volatility than the preceding bear (bull) market. Volatility fell from 102 per cent of its whole-sample average in the 1990 bear market, to 96 per cent in the 1994 bear market. In the bull markets, it fell from 85 per cent in 1991-1993 to 74 per cent in 1995. In contrast, in the bond market, which has a positive trend, each bull market had higher volatility than did its predecessor. Volatility was 87 per cent of its whole-sample average in the 1990-93 bull market and 107 per cent in 1995.

5.1.2 Do market falls cause greater volatility than market rises?

To investigate whether or not market falls cause greater volatility than market rises, the following equation was estimated for the bond and share markets:

$$v_t = a + bv_{t-1} + g^+ \Delta_t^+ + g^- \Delta_t^- + e_t \qquad (18)$$

where: v_t is the volatility at time t, Δ_t^+ is the absolute value of a market rise and Δ_t^- is the absolute value of a market fall at time t. Obviously Δ_t^+ and Δ_t^- are mutually exclusive. For bonds, market movements are measured by the basis point change in yields; for the share market the percentage change in the All Ordinaries index is used.

24 The difference-in-means test does not take into account the persistent nature of volatility. Tests allowing for this autoregressive aspect of volatility would be required before one could conclude with any certainty that bear markets *generate* greater volatility than bull markets.

Two sets of equations were estimated for each market. In the first, weekly averages of daily data were used in the regressions. In the second set, market changes were given by the weekly (Friday-to-Friday) change in the market level. Weekly averages of daily data were again used for volatility. To allow for the high degree of persistence in volatility, the equations were estimated using robust errors.

If an asymmetry exists, the coefficients of the market change variables will be different. In particular, g^- will be greater than g^+ if market falls are associated with higher volatility than market rises. The results are recorded in Table 4. They provide support for the thesis that market falls cause higher volatility.

Table 4: Volatility and Market Movements – Regression Results

Market	Constant α	Lagged volatility v_{t-1}	Market rise g^+	Market fall g^-	$\bar{R}^2$
Bond					
Δ*weekly average*	0.01** (0.00)	0.82*** (0.03)	0.28*** (0.04)	0.39*** (0.09)	0.78
Weekly change	0.01** (0.00)	0.82*** (0.02)	0.06*** (0.01)	0.08*** (0.01)	0.78
Share					
Δ*weekly average*	0.03* (0.02)	0.74*** (0.02)	0.36*** (0.06)	0.75*** (0.12)	0.93
Weekly change	0.03* (0.02)	0.74*** (0.02)	0.07*** (0.01)	0.15*** (0.02)	0.93

Notes: (a) Standard errors robust to serial correlation and heteroscedasticity are presented in parentheses below the coefficient estimates.

(b) Δ*weekly average* refers to regressions using weekly averages of daily data. *Weekly change* refers to regressions using weekly (Friday-to-Friday) changes for market changes and weekly averages of daily data for volatility.

(c) ***, **, * indicate that coefficients are significantly different from zero at 1%, 5% and 10% respectively.

The coefficients for market falls are clearly greater than those for market rises.[25] The difference in the coefficients is stronger for shares than for bonds, with the

[25] The null hypothesis that g^- equals g^+ is rejected at the 1% level for both the bond and share markets.

market fall coefficient more than twice the market rise coefficient. This supports the observation, noted above, that the asymmetry is stronger in the share market than in the bond market. For both markets one may conclude that there is an asymmetry in the response of volatility to market movements, with falls being associated with higher volatility than rises.

5.2 Asymmetry in Market Linkages

Previous parts of this paper have investigated the linkages between markets, in terms of both their volatility and the movements of their levels. This section addresses the issue of whether asymmetries exist in such linkages. Specifically, it considers three questions. The first is whether volatility is more correlated in periods of high volatility than in periods of low volatility. Secondly, are market movements more correlated in bear markets than in bull markets? Finally, is volatility more correlated in bear markets than in bull markets?

Semi-correlations are used to determine whether correlations differ depending upon the level of volatility or market movements. Semi-correlations measure the correlation of two series in three states of the world: up-up (both series are above their means), down-down (both series are below their means) and mixed (one series is above its mean and the other is below).[26] There is no statistical reason why above average volatility or market movements should have a different correlation from those below the mean. Thus, different correlations in the up-up and down-down states indicate an asymmetry in the relationship.

5.2.1 Is volatility more correlated in periods of high volatility?

Table 5 contains the semi-correlations of volatility in Australian and US markets. Seventeen of the 21 relationships have stronger correlations in the '*up-up*' markets. This is cogent evidence that the correlation of volatility across markets is stronger during periods of above average volatility. Some of the differences between correlations in the two states are very dramatic. In particular, the relationships between share and bond markets, both within each country and internationally, show a marked asymmetry in correlations.

---

[26] See Erb, Harvey and Viskanta (1994).

The asymmetry appears to be weak for foreign exchange markets. The correlation difference is generally low for relationships including an exchange rate. The four relationships which have stronger correlations in down-down markets all involve exchange rates. Given the unusual status of exchange rates this is perhaps not surprising. The relationships between asset (ie bond and share) markets uniformly have stronger correlations in the up-up state of the world.

5.2.2 Are market movements more correlated in bear markets?

Table 6 contains the semi-correlations of changes in market levels in Australian and US markets. Twelve of the 21 relationships have stronger correlations in the down-down markets, nine in the up-up markets. This does not indicate any systematic asymmetry in the relationships. It is, however, notable that all of the intra-Australia relationships have stronger correlations in the down-down markets. In Australia at least, it may be that markets do show greater co-movement in bear markets.

In general the results do not show large disparities between correlations in the two states. The largest difference is for share(US)-share(Australia), and this result is probably heavily influenced by the 1987 stock-market crash. Those relationships with stronger correlations in bull markets do not provide significant evidence of an asymmetry in favour of bull markets as they generally involve movements around near-zero correlation. The share(US)-yen and bond(US)-US$/$A relationships are exceptions, as they both have significant levels of correlation in the up-up markets. An interesting result is that for the bond(US)-bond(Australia) relationship. It shows effectively no change in correlation for the different states.

5.2.3 Is volatility more correlated in bear markets?

Table 7 reports the correlations of volatility depending upon the state of market movements. Note that it takes a slightly different approach to that in Table 5, as it uses market movements to define the up-up, down-down and mixed states, not the state of volatility.

Thirteen of the 21 relationships are stronger in the down-down, or bear, markets. This provides some suggestion of a tendency for volatility to be more correlated in bear markets, but the evidence is neither universal nor overly strong.

Again, all of the eight relationships which have stronger correlations in the up-up, or bull, markets involve exchange rates. The other seven relationships involving exchange rates have stronger correlations in the down-down markets. This indicates that no asymmetry exists in the foreign exchange markets. As mentioned above, given the unusual status of exchange rates and the difficulty of defining bull and bear markets with respect to them, this is not a surprising result.

An alternative view of these results is that bond and share markets are characterised by an asymmetry in their volatility correlations. Every combination involving only bond and share markets (ie any relationship not involving an exchange rate) has stronger volatility correlations in bear markets. Of course, to the extent that bear markets are associated with higher than usual volatility, this result replicates the first finding that volatility is more correlated in periods of high volatility. Some of the differences in correlation are marked. For example, see the share(US)-bond(US), bond(US)-share(Australia) and bond(US)-bond(Australia) relationships.

Table 5: Semi-Correlation of Volatility

Asset pair	Up-up correlation	Down-down correlation	Mixed correlation	Total correlation
Intra-Australian markets				
Share-bond	0.77	-0.11	-0.53	0.50
Share-US$/$A	-0.35	0.12	-0.56	0.25
Share-TWI	0.25	0.17	-0.33	0.21
Bond-TWI	0.32	0.22	-0.56	0.36
Bond-US$/$A	0.25	-0.10	-0.59	0.18
TWI-US$/$A	0.67	0.29	-0.49	0.64
Intra-US markets				
Share-bond	0.77	0.12	-0.50	0.67
Share-Yen/US$	0.81	-0.02	-0.59	0.12
Bond-Yen/US$	0.025	0.11	-0.53	0.18
Inter-country markets				
Share(US)-Share(A)	0.95	0.07	-0.29	0.92
Share(US)-Bond(A)	0.98	0.00	-0.57	0.39
Share(US)-US$/$A	0.11	-0.04	-0.47	0.25
Share(US)-TWI	0.31	-0.18	-0.38	0.11
Bond(US)-Share(A)	0.73	0.07	-0.53	0.64
Bond(US)-Bond(A)	0.63	-0.33	-0.58	0.45
Bond(US)-US$/$A	0.33	0.11	-0.45	0.37
Bond(US)-TWI	0.24	0.37	-0.48	0.17
Yen/US$-Share(A)	-0.037	0.05	-0.47	0.10
Yen/US$-Bond(A)	-0.16	0.013	-0.58	0.07
Yen/US$-US$/$A	0.046	0.22	-0.44	0.22
Yen/US$-TWI	0.16	0.09	-0.56	0.28

Notes: The semi-correlations measure the correlation of volatility in three states of the world: up-up (volatility in both markets is above the mean), down-down (volatility in both markets is below the mean) and mixed (one market's volatility is above the mean, the other below). Correlations are calculated from weekly averages of daily data. The sample is for week-ending 15/5/87 to week-ending 2/2/96.

Table 6: Semi-Correlation of the Change in Market Levels

Asset pair	Up-up correlation	Down-down correlation	Mixed correlation	Total correlation
Intra-Australian markets				
Share-bond	-0.09	-0.28	0.56	-0.35
Share-US$/$A	-0.03	0.21	-0.60	0.14
Share-TWI	0.08	0.20	-0.61	0.12
Bond-TWI	-0.19	-0.27	0.56	-0.11
Bond-US$/$A	0.05	-0.16	0.56	-0.16
TWI-US$/$A	0.48	0.78	-0.52	0.77
Intra-US markets				
Share-bond	-0.19	-0.32	0.75	-0.13
Share-Yen/US$	0.21	0.03	-0.53	0.09
Bond-Yen/US$	-0.16	0.10	0.52	0.02
Inter-country markets				
Share(US)-Share(A)	0.06	0.62	-0.55	0.37
Share(US)-Bond(A)	-0.12	-0.07	0.55	-0.16
Share(US)-US$/$A	0.03	0.10	-0.62	-0.07
Share(US)-TWI	-0.10	0.01	-0.61	-0.02
Bond(US)-Share(A)	0.01	-0.04	0.73	0.26
Bond(US)-Bond(A)	0.15	0.14	-0.59	0.19
Bond(US)-US$/$A	-0.19	0.06	0.52	0.09
Bond(US)-TWI	-0.05	-0.04	0.50	0.05
Yen/US$-Share(A)	-0.09	0.00	-0.61	0.03
Yen/US$-Bond(A)	-0.08	-0.01	0.55	0.03
Yen/US$-US$/$A	0.07	0.24	-0.65	-0.06
Yen/US$-TWI	0.22	0.23	-0.55	0.33

Notes: The semi-correlations measure the correlation of changes in market levels in three states of the world: up-up (the change in market levels in both markets is above the mean), down-down (the change in levels in both markets is below the mean) and mixed (one market's change in level is above the mean, the other below). The change in market level is measured by the daily percentage change in the relevant share index or exchange rate. For bonds, the daily basis point change is used. Correlations are calculated from weekly averages of daily data. The sample is for week-ending 15/5/87 to week-ending 2/2/96.

Table 7: Correlations of Volatility Based on Change in Market Levels

Asset pair	Up-up correlation	Down-down correlation	Mixed correlation	Total correlation
Intra-Australian markets				
Share-bond	0.44	0.53	0.50	0.50
Share-US$/$A	0.27	0.23	0.28	0.25
Share-TWI	0.21	0.26	0.19	0.21
Bond-TWI	0.40	0.24	0.41	0.36
Bond-US$/$A	0.37	0.16	0.04	0.18
TWI-US$/$A	0.52	0.73	0.67	0.64
Intra-US markets				
Share-Bond	0.39	0.86	0.62	0.67
Share-Yen/US$	0.24	0.14	0.09	0.12
Bond-Yen/US$	0.15	0.18	0.19	0.18
Inter-country markets				
Share(US)-Share(A)	0.67	0.94	0.94	0.92
Share(US)-Bond(A)	0.41	0.60	0.26	0.39
Share(US)-US$/$A	0.19	0.08	0.33	0.25
Share(US)-TWI	-0.15	0.11	0.19	0.11
Bond(US)-Share(A)	0.46	0.84	0.32	0.64
Bond(US)-Bond(A)	0.24	0.55	0.52	0.45
Bond(US)-US$/$A	0.44	0.33	0.36	0.37
Bond(US)-TWI	0.20	0.26	0.05	0.17
Yen/US$-Share(A)	-0.01	0.14	0.15	0.10
Yen/US$-Bond(A)	0.08	0.06	0.05	0.07
Yen/US$-US$/$A	0.20	0.26	0.22	0.22
Yen/US$-TWI	0.21	0.42	0.20	0.28

Notes: The correlations measure the correlation of volatility in three states of the world: up-up (the change in market levels in both markets is above the mean), down-down (the change in levels in both markets is below the mean) and mixed (one market's change in level is above the mean, the other below). The change in market level is measured by the daily percentage change in the relevant share index or exchange rate. For bonds, the daily basis point change is used. Correlations are calculated from weekly averages of daily data. The sample is for week-ending 15/5/87 to week-ending 2/2/96.

6. Conclusion

An analysis of daily asset price fluctuations in Australia's bond, share and foreign exchange markets over the period 1987 to 1996, does not suggest the presence of a trend increase in Australian financial market volatility. Episodes during which volatility records quite sizeable increases can be observed. These episodic surges in volatility however are not maintained. Rather they are generally short-lived events, with volatility returning relatively quickly to its underlying or background level.

With respect to each of the key Australian financial markets, the following general observations can be made regarding their respective volatility profiles.

Daily volatility in the *Australian bond market* is higher on average than other markets, and displays greater variability over time. While econometric tests suggest the presence of a slight positive trend in volatility, this is probably a statistical consequence of the high and relatively persistent volatility episode late in the sample period, rather than evidence of a trend increase.

No secular upward trend can be observed in daily *Australian share-market* volatility. To the contrary, econometric tests and visual inspection of the data suggest the presence of a slight downward trend in Australian share-market volatility over the period. This is a feature shared by other national markets, with the exception of the Japanese stock market. In contrast to the bond market, Australian share-market volatility is not high in international terms and comparable to the US and UK market averages.

The volatility of daily percentage changes in the USD/AUD exchange rate records the lowest period average out of the five currencies that are examined. Econometric tests as well as visual inspection, reveal a clear downward trend in the volatility profile of the USD/AUD nominal exchange rate. These tests however also reveal a slight positive trend in the volatility of the TWI, possibly reflecting the higher volatility of the JPY/USD exchange rate in recent years.

With regard to the issue of cross-country and cross-market linkages, the following general results emerge. Correlation analysis and econometric tests provide evidence of quite significant cross-country 'contagion' or 'spillover' effects impacting on Australia's bond and equity markets. For both of these markets, the predominant foreign market influence is the US. For the Australian bond market, an increasing dependence on daily yield fluctuations in the US bond market is clearly evident. This pronounced spillover effect from the US to Australian bond markets, however, becomes readily apparent only from late 1993 onwards. The evidence also seems to suggest that this increased responsiveness displayed by the Australian bond market to overnight changes in US bond yields is not a transient event, but, rather, a structural change in the relationship between the two markets.

Significant spillover effects from the US to Australian equity markets also exist. Unlike the case for bond markets however, daily price fluctuations in the US share market have an important influence on Australian share prices throughout the nine year sample period. The magnitude of 'contagion' is not constant over time, its variation over the period is quite significant with spillovers becoming most pronounced during episodes of severe financial market turbulence.

Extending the examination to explicitly consider both cross-country and cross-market linkages between Australian and US financial markets, evidence exists to suggest that cross-country spillovers within the market for the same asset are more pronounced than cross-market spillovers within the same country. Thus for the Australian bond market the most important influence is developments in the US bond market, followed by those in Australian share market. Similarly the Australian share market is more closely influenced by US share prices than by fluctuations in Australian bond yields.

Finally, volatility in Australian bond and share markets is found to exhibit marked asymmetries. For both markets, volatility is, on average, higher during bear markets than it is during bull markets. Also market falls are found to engender greater volatility than market rises of equal magnitude. Volatility is found to be more correlated both across countries and markets during periods of high volatility than in periods of low volatility, and in bear markets more than in bull markets.

References

Bank for International Settlements (1996), *Financial Market Volatility: Measurement, Causes, and Consequences,* BIS Conference Papers Vol. 1, March.

Bertero, E. and C. Mayer (1990), ‘Structure and Performance: Global Inter-Dependence of Stock Markets around the Crash of October 1987’, *European Economic Review*, 34(6), pp. 1155-1180.

Black, F. (1976), ‘Studies of Stock Market Volatility Changes’, *Proceedings of the American Statistical Association, Business and Economics Association*, pp. 177-181.

Borio, C.E.V. and R.N. McCauley (1996), ‘The Economics of Recent Bond Yield Volatility’, BIS Economic Papers No. 45, July.

Erb, B.E., C.R. Harvey and T.E. Viskanta (1994), ‘Forecasting International Equity Correlations’, *Financial Analysts Journal*, Nov.-Dec., pp. 32-45.

Eun, C. and S. Shim (1989), ‘International Transmission of Stock Market Movements’, *Journal of Financial and Quantitative Analysis*, 24(2), pp. 241-256.

Hamao, Y., R. Masulis and V. Ng (1990), ‘Correlations in Price Changes and Volatility Across International Stock Markets’, *Review of Financial Studies*, 3, pp. 281-307.

King, M. and S. Wadwhani (1990), ‘Transmission of Volatility Between Stock Markets’, *Review of Financial Studies*, 3(1), pp. 5-33.

Koch, P. and Koch, R. (1991), ‘Evolution in Dynamic Linkages Across Daily National Stock Indices’, *Journal of International Money and Finance*, 10(2), pp. 231-251.

Lin, W-L. and T. Ito (1994), ‘Price Volatility and Volume Spillovers between the Tokyo New York Stock Markets’, in J.A. Frankel (ed), *The Internationalization of Equity Markets*, University of Chicago Press, Chicago, pp. 309-333.

Roll, R. (1989), ‘Price Volatility, International Market Links, and their Implications for Regulatory Policies’, *Journal of Financial Services Research*, 3(2/3), pp. 211-246.

von Furstenberg, G. and B. Jeon (1989), ‘International Stock Price Movements: Links and Messages’, in W.C. Brainard and G.L. Perry (eds), *Brookings Papers on Economic Activity*, Brookings Institution, Washington, D.C, pp. 125-179.