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How Important Are Meteor Showers and Heat Waves in Exchange Rate Volatility?

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HOW IMPORTANT ARE METEOR SHOWERS AND HEAT WAVES IN EXCHANGE RATE VOLATILITY?*

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Applied research has devoted considerable resources attempting to understand sources of exchange rate volatility. One stream of literature associates exchange rate volatility with 'news' releases. Engle, Ito and Lin (1990) introduced the idea of geographical news effects, with 'heat waves' representing local events and 'meteor showers' events with global impact. Mahieu and Schotman (1994) modelled exchange rate changes as a linear combination of local and global events. This paper generalises from the insights of Mahieu and Schotman and produces a model where bilateral exchange rate changes can be viewed as a linear combination of reactions to three unobserved factors: world events and events specifically related to the currencies involved in the exchange rate. Using this model it is possible to go further than previous results and produce GMM estimates of the contributions that domestic, foreign and world news factors make to exchange rate volatility. The results show that the relative impact of international and domestic news varies considerably over the exchange rates involved.

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HOW IMPORTANT ARE METEOR SHOWERS AND HEAT WAVES IN EXCHANGE RATE VOLATILITY?

1. Introduction

The move from fixed to floating exchange rate regimes resulted in well-documented increases in short-term volatility in exchange rates (for example Hasan and Wallace (1996)). Research interest has focussed on searching for the sources of exchange rate changes, as most authors concur that understanding the source of exchange rate volatility is fundamental to the decision on whether it should be reduced by official actions (Collinge (1994) provides an alternative view). Some particular avenues have been: the behaviour of economic fundamentals (Rose (1994)); chaos models (Rao (1993)); and market reaction to 'news' announcements. The latter has been a particularly fertile area of research with investigations covering news such as the effects of particular statistical releases (for example the US trade balance in Sultan (1994) and Hogan and Melvin (1994)), political and social events (Melvin and Tan (1996)) and expectations using survey data (Frankel and Froot (1987), Koedijk and Wolff (1996)).

The empirical literature has explored exchange rate volatility across a range of exchange rates, with some authors concerned to note differences and similarities across different rates and regimes (Rose (1994), Boulton, Dungey and Parkin (1991)). No clear conclusion on the sources of exchange rate volatility has emerged from the standard literature.

In one variation on the news theme, exchange rate volatility has been associated with the geographical origin of 'news', an idea introduced by Engle, Ito and Lin (1990). Their original hypothesis was that observed persistence in exchange rate volatility may be primarily due to 'heat waves' in which the effect of local news tended to persist, or alternatively due to 'meteor showers' where events impacted around the world in a sequential manner. Hogan and Melvin (1996) combine the geographical and specific news approaches.

In a new approach to understanding exchange rate volatility Mahieu and Schotman (1994) took the geographical source of exchange rate shocks a step further. Under their hypothesis, movements in a particular exchange rate can be considered as due to a linear combination of local events (heat waves) and international events (meteor showers). In a further innovation, Mahieu and Schotman only associate news geographically. The factors causing exchange rate changes are unobservable, and are identified only by their geographical impact. Their paper produces a ranking of the relative importance of domestic and international 'news' in bilateral exchange rate volatility for four major currencies, without identifying the particular instances of that news.

This paper generalises from the insights of Mahieu and Schotman, by including full information on the covariances between bilateral exchange rates. To do this a new model of exchange rate changes is proposed, whereby changes in any bilateral exchange rate can be viewed as a linear combination of reactions to three unobserved factors. These factors are identified as world events, and events specifically related to each of the two currencies involved in the particular bilateral exchange rate. Using this model it is possible to go further than the results of Mahieu and Schotman and produce estimates of the contributions that domestic, foreign and world news factors make to exchange rate volatility. The results show that the relative contributions of international and domestic news vary considerably over the exchange rates involved.

Section 2 of this paper outlines the proposed three factor model of exchange rate changes and shows how this can be used to examine volatility. Section 3 estimates the contribution of domestic, foreign and world factors to volatility in a panel of seven currencies (giving a total of 21 bilateral exchange rates). From these estimates some generalisations follow about the relative importance of domestic and international news factors for volatility in several groups of exchange rates.

2. The Model

Consider (1) as a general form of a model of exchange rate changes determined by M independent factors.

$$s_{io} = \sum_{j=1}^{M} f_{ij} b_{ij} \qquad (1)$$

where s_{io} is the change in the log of a bilateral spot exchange rate expressed as currency i against currency 0, f_{ij} are the independent factors and b_{ij} are response parameters. If the factors were not uncorrelated then the model could be reparameterised with a new set of uncorrelated factors. Hence, the factors are defined through their lack of correlation rather than being given 'names'.

The factors explaining exchange rate changes in this paper are unobservable as per Mahieu and Schotman (1994). The parameters of the problem can be estimated using a set of moment conditions, but not through simple regression analysis.

Consider a system of n bilateral exchange rates expressed against a common numeraire currency, so that there are n+1 currencies in the system. For ease of exposition each currency is uniquely associated with one issuing country.

On the basis that a panel of exchange rate data used for a study such as this is not singular (hence ruling out the inclusion of exchange rates involved in monetary unions and other such managed agreements) then there will be at least as many explanatory factors as exchange rates in the model, that is $M \geq n$.

Changes in each of the bilateral exchange rates are determined by a linear combination of the M factors as in (1). Stacking expressions for different exchange rates produces a system of equations:

$$s = Bf \qquad (2)$$

where s is an nx1 vector or stacked exchange rates and B is an nxM matrix of coefficients. Then

$$var(s) = B var(f) B' \qquad (3)$$

The matrix var(s) has at most n(n+1)/2 unique elements which can be used to identify parameters. Hence the necessary conditions for identification in the system will depend on the relationship between the number of factors, M, and the number of exchange rates, n. Importantly, volatility in exchange rates is generally measured as the variance of changes in exchange rates.

This paper proposes a particular form for the factor model of exchange rate changes based on three independent factors, as given in (4).

$$s_{io} = \beta_i f_w + \alpha_i f_i + \alpha_0 f_0 \tag{4}$$

The factors are: f_w the world factor; f_i a factor uniquely associated with currency i, and f_0 a factor uniquely associated with currency 0. The world factor, f_w affects all bilateral exchange rate changes, but the response to that factor, β_i, differs between exchange rates. To give an example, if f_w was a world oil price shock the Japanese yen - US dollar exchange rate would be expected to react differently to the UK pound-US dollar exchange rate.

Through arbitrage any given factor f_i will have the same response parameter, α_i on an exchange rate involving currency i. To see this consider a three currency example where the response parameters to particular currencies differ for each exchange rate. Define S_{USA} as the spot exchange rate of Australian dollars for US dollars, S_{JA} as the spot exchange rate of Australian dollars for Japanese yen and S_{USJ} as the spot exchange rate of Japanese yen for Australian dollars. According to (4) the three exchange rates would be modelled as:

$$s_{USA} = \beta_1 f_w + \alpha_1 f_{US} + \alpha_0 f_A \tag{5}$$

$$s_{JA} = \beta_2 f_w + \alpha_2 f_J + \alpha_3 f_A \tag{6}$$

$$s_{USJ} = \beta_3 f_w + \alpha_4 f_{US} + \alpha_5 f_J \tag{7}$$

Arbitrage in foreign exchange markets implies $S_{ij}=S_{ik}/S_{jk}$. There is a potential error here due to Jensen's inequality, however in high frequency data this is unlikely to be a problem. Hence

$$S_{USJ} = S_{USA} / S_{JA} \tag{8}$$

$$\Rightarrow s_{USJ} = s_{USA} - s_{JA} \tag{9}$$

Substituting equations (5), (6) and (7) into (9):

$$\beta_3 f_w + \alpha_4 f_{US} + \alpha_5 f_J = \beta_1 f_w + \alpha_1 f_{US} + \alpha_0 f_A - \beta_2 f_w - \alpha_2 f_J - \alpha_3 f_A \quad (10)$$

For this equation to hold for arbitrary factor values, the coefficients on each of the individual factors on both sides of equation (10) must be equal. Hence, the following conditions must hold.

$$\beta_3 - \beta_1 + \beta_2 = 0 \quad (11)$$

$$\alpha_4 - \alpha_1 = 0 \quad (12)$$

$$\alpha_5 + \alpha_2 = 0 \quad (13)$$

$$\alpha_0 - \alpha_3 = 0 \quad (14)$$

These restrictions mean that (5), (6) and (7) can be rewritten as:

$$s_{USA} = \beta_1 f_w + \alpha_1 f_{US} + \alpha_0 f_A \quad (15)$$

$$s_{JA} = \beta_2 f_w + \alpha_2 f_J + \alpha_0 f_A \quad (16)$$

$$s_{USJ} = \beta_3 f_w + \alpha_1 f_{US} - \alpha_2 f_J \quad (17)$$

Arbitrage results in the condition that the absolute value of α_i on a factor f_i will be the same for any exchange rate involving currency i in the system. Further, the use of arbitrage also means that there is no need to estimate the parameters on the cross rate separately, as they can be constructed from the estimates of the other coefficients - using (11) s_{USJ} can be written as:

$$s_{USJ} = (\beta_1 - \beta_2) f_w + \alpha_1 f_{US} - \alpha_2 f_J \quad (18)$$

Hence in any panel of exchange rates against a common numeraire currency the system will exhibit a common factor associated with the numeraire currency.

For the system (15) and (16) to be identified requires that $\beta_I \neq \beta_2$; that is the response coefficient to world shocks cannot be the same for these two exchange rates. In practice we will need β_I well distanced from β_2 otherwise the system will be nearly unidentified. Of course with n rates we need the elements of vector β_i to be sufficiently different, a condition which is unlikely to be violated when n is large.

The final model therefore has two common factors - the common world factor, which has differing effects on each exchange rate change, and the common numeraire factor which affects each exchange rate change equally. These two factors can be separated from each other due to the structure of (15) and (16). Only a numeraire factor shock causes both (15) and (16) to change by the same amount, the world shock captures common factor movements, but with differing response coefficients. The other country factor captures movements unique to the individual exchange rate.

Using this approach a system of equations such as (19) can be estimated, with n exchange rates and M=n+2 factors in the equation.

$$\begin{bmatrix} s_{10} \\ s_{20} \\ .. \\ s_{n0} \end{bmatrix} = \begin{bmatrix} \beta_1 & \alpha_0 & \alpha_1 & 0 & .. & 0 \\ \beta_2 & \alpha_0 & 0 & \alpha_2 & .. & 0 \\ .. & .. & .. & .. & .. & .. \\ \beta_n & \alpha_0 & 0 & 0 & .. & \alpha_n \end{bmatrix} \begin{bmatrix} f_w \\ f_0 \\ f_1 \\ f_2 \\ .. \\ f_n \end{bmatrix} \qquad (19)$$

There are n parameters relating to the world factor (the β_i), and n+1 relating to idiosyncratic factors (the α_i). The following necessary identification condition applies.

$$n(n+1)/2 \geq n + n + 1$$

$$\Rightarrow \qquad n \geq 4$$

The matrix B can be estimated with a minimum of 4 bilateral exchange rates against a common numeraire, although the factors themselves cannot be identified while M>n.

The moment conditions produced from var(s)=Bvar(f)B' are not immediately useful, however, under the assumption that $var(f)=I_{n+2}$, moment conditions of the following form emerge.

$$m_1(\theta) = var(s_{10}) - \{\beta_1^2 + \alpha_1^2 + \alpha_0^2\} \qquad (20)$$

$$m_2(\theta) = \mathrm{cov}(s_{10}, s_{20}) - (\beta_1\beta_2 + \alpha_0^2) \qquad (21)$$

Setting var(f)=I_{n+2} is used as var(f) is itself unobserved. To the extent this assumption is violated the parameter estimates will absorb the true variance of the unobserved estimates. That is, an estimate of α_i will in fact be an estimate of $\alpha_i\sqrt{\mathrm{var}(f_i)}$ with the result that comparing the absolute values of the coefficients is not very informative. However, the contribution of each of the unobserved factors to total volatility in an exchange rate is available through the moment conditions given by (20), and the true value of var(f_i) does not impinge on these results. Hence from estimates of α_i and β_i the following decompositions can be obtained.

$\frac{\alpha_0^2}{\mathrm{var}\, s_{i0}}$ = contribution of the numeraire currency factor to volatility in the exchange rate

$\frac{\alpha_i^2}{\mathrm{var}\, s_{i0}}$ = contribution of currency i factor to volatility in the exchange rate

$\frac{\beta_i^2}{\mathrm{var}\, s_{i0}}$ = contribution of the world factor to volatility in the exchange rate

The model is well-suited to estimation by GMM (see Hamilton (1994)), using the Hansen (1982) solution to account for an excess of moments over unknown parameters. Several points are worth noting. First, the process involves an initial consistent estimate of the parameter matrix using the identity matrix as weights before proceeding to efficient estimates using a weighting matrix based on the variance-covariance matrix estimated in the first step. Second, concerns over possible autocorrelation in determining the weighting matrix are addressed in this paper using the estimator suggested by Newey and West (1987)[1].

[1] Full details of the estimation procedure are contained in Dungey (1997). The Gauss v.3.25 programs used are available from the author on request.

3. Data and estimation

A panel of centred weekly changes in exchange rates constructed from seven currencies was used for this study. The data were extracted from a Reserve Bank of Australia database of 4p.m. Sydney Wednesday observations[2] from December 1983 to December 1994, giving a total of 576 observations. Currencies were selected on the basis that they were within the world top 10 currencies by turnover (BIS (1992)) and independently floating since 1984. The chosen currencies were the US dollar (USD), Japanese yen (JPY), Deutschemark (DEM), British pound sterling (GBP), Canadian dollar (CAD) and Australian dollar (AUD).

As well as centering the exchange rate changes, four particular episodes of volatility were dummied for in the estimations. These were the ERM realignment of 1992, the stock market crash of 1987, the period surrounding the Plaza Accord in 1985 and a disturbance to the Australian foreign exchange market in 1989 due to reaction to a current account announcement[3]. If these readily identifiable disturbances to the markets are not removed they tend to dominate the results because the approach does not allow for time-varying factor influences – which is an avenue for further research.

With a set of seven currencies, seven panels of exchange rate changes against a common numeraire currency can be examined. In the estimation process it became apparent that the efficient estimates produced are unstable, a point that was only

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[2] If Wednesday was a non-trading day Thursday's observation was used, and if that also was unavailable Tuesday's observation was chosen. Thursday observations were used a total of 6 times on 26-April-1984, 27-December-1984, 26-April-1990, 27-December-1990, 3-October-1991 and 27-January-1994 (in each case the preferred date was the day before which was a non-trading day on the Sydney exchange). Tuesday observations were used a total of 4 times; on 24-December-1985, 31-December-1985, 24-December-1991 and 31-December-1991 (in each case the preferred date was the day after, but both the Wednesday and Thursday were public holidays in the Australian market).

[3] In particular the periods dummied for were the 14 weeks from 30-Jan-1985 to 1-May-1985 in the lead up to the Plaza Accord; the 28-October-1987 for the stock market crash; the 15-February-1989 for the current account announcement in Australia and the three weeks from 9-September-1992 to 23-September-1992 for the ERM realignment. In all 19 observations had associated dummy values.

established using recursive estimation. This paper therefore concentrates on the consistent parameter estimates. As aforementioned the parameter estimates themselves are not particularly interesting. Table 1 presents the contributions of each factor to volatility in bilateral exchange rates according to the numeraire currency. The same information is presented in Charts 1 to 7.

Table 1: Variance Contributions with different Numeraire Currencies

exchange rate	contribution of factors(%)			exchange rate	contribution of factors(%)			exchange rate	contribution of factors(%)		
s_{ij}	f_i	f_w	f_j	s_{ij}	f_i	f_w	f_j	s_{ij}	f_i	f_w	f_j
USD/AUD	11.0	0.7	88.4	DEM/USD	3.08	88.3	8.7	JPY/USD	59.0	38.1	3.0
USD/CAD	54.3	0.0	45.7	DEM/AUD	2.1	59.2	38.8	JPY/DEM	65.7	28.4	6.0
USD/JPY	10.3	33.2	56.5	DEM/JPY	4.6	29.7	65.7	JPY/AUD	35.9	18.4	45.7
USD/DEM	7.6	87.9	4.5	DEM/GBP	7.7	6.3	86.0	JPY/GBP	45.8	6.0	48.3
USD/CHF	6.8	87.3	5.9	DEM/CAD	3.0	89.1	7.9	JPY/CAD	25.8	29.6	17.6
USD/GBP	6.9	59.6	33.5	DEM/CHF	22.0	0.1	77.9	JPY/CHF	63.4	36.6	0.0
GBP/USD	33.2	58.5	8.4	CHF/USD	4.7	87.8	7.47	CAD/USD	53.7	0.0	46.3
GBP/DEM	91.0	9.1	0.0	CHF/DEM	38.4	3.7	57.9	CAD/DEM	7.5	87.9	4.6
GBP/JPY	38.4	9.8	51.8	CHF/JPY	7.9	31.2	60.9	CAD/JPY	9.1	35.4	55.5
GBP/AUD	25.5	35.1	39.4	CHF/GBP	11.2	10.3	78.5	CAD/GBP	7.3	57.5	35.2
GBP/CAD	35.3	58.1	6.6	CHF/CAD	4.7	89.3	6.1	CAD/AUD	11.5	0.4	88.2
GBP/CHF	76.8	8.7	14.5	CHF/AUD	3.4	58.9	37.7	CAD/CHF	6.6	88.3	5.0
AUD/USD	82.6	0.0	17.4	AUD/JPY	47.4	17.6	35.0	AUD/CHF	37.1	58.4	4.5
AUD/CAD	87.6	0.3	12.1	AUD/DEM	38.7	59.2	2.1	AUD/GBP	40.2	35.0	24.8

Chart 1

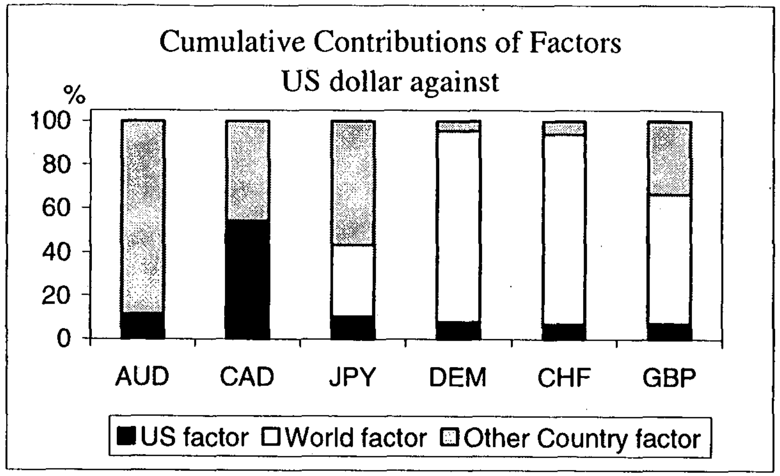


Chart 2

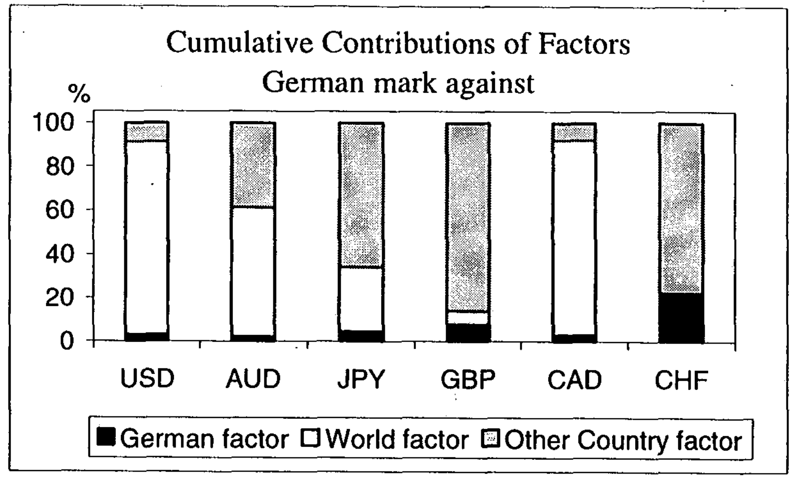


Chart 3

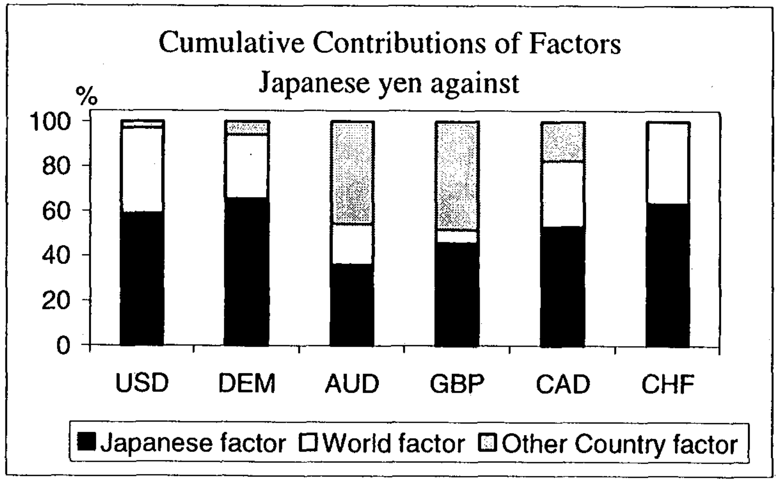


Chart 4

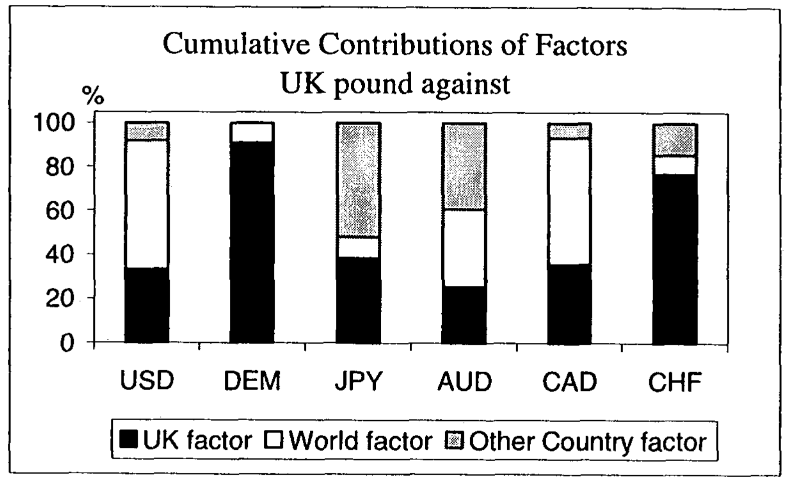


Chart 5

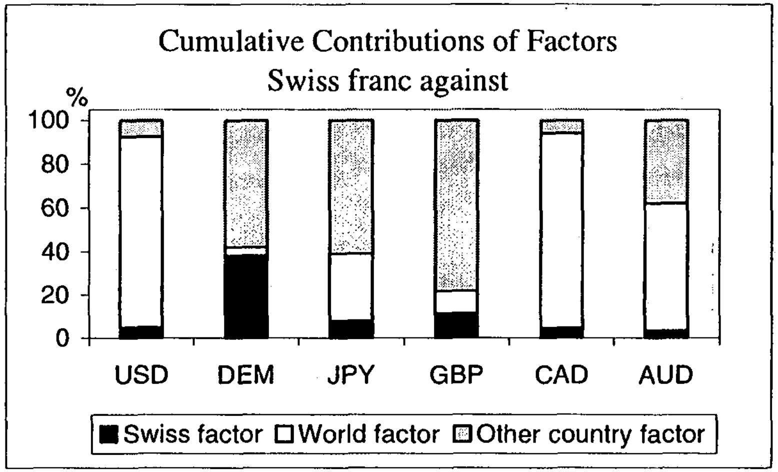


Chart 6

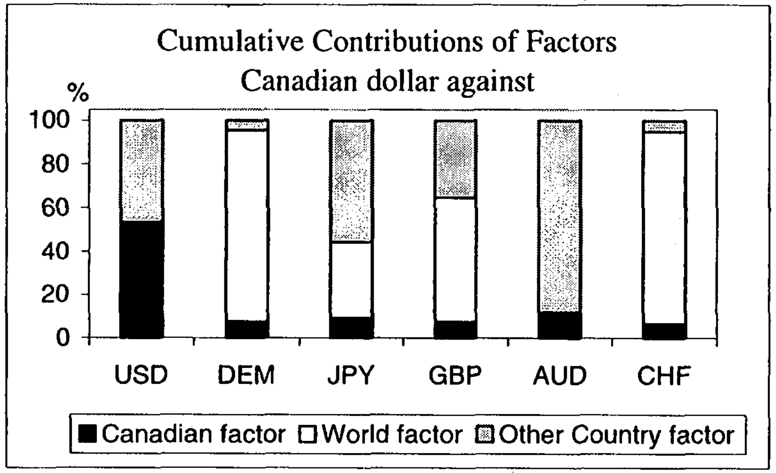
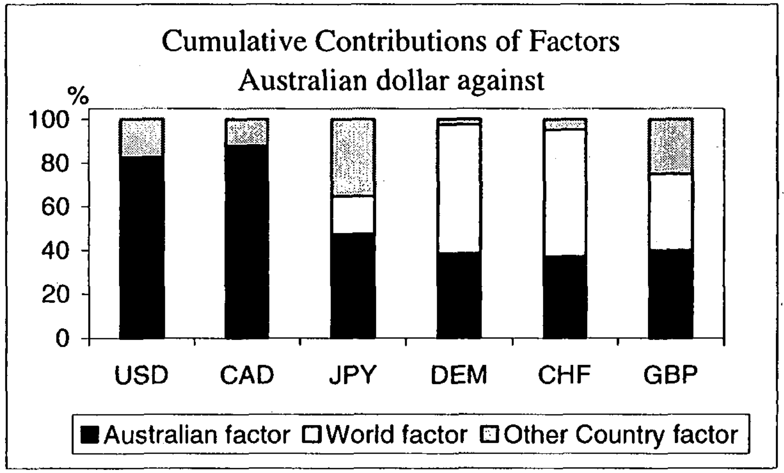


Chart 7



According to the analysis of the previous section, the choice of numeraire currency should make no difference to the contributions of each factor to volatility in a particular exchange rate. In most cases, this is demonstrably true in Table 1. For example, the contributions of the DEM, AUD and world factors to volatility in the exchange rate of the German mark and the Australian dollar are 2 percent, 39 percent and 59 percent respectively, regardless of which currency is used as the numeraire. However, some of the exchange rates do not show this correspondence across different numeraires. In particular, the exchange rates JPY/CAD, JPY/CHF, JPY/GBP, JPY/USD, CHF/DEM and AUD/USD show unexpectedly large differences in the contributions of the components.

The cause of the differences between the estimated coefficients when using different numeraires lies in the estimation procedure. In reality a system of equations is being estimated with one equation dropped. In principle the estimated results should be invariant to which equation is dropped. This would be the case in maximum likelihood estimation (Greene (1993:p501)). However, fixing W=I means the estimations here are not equivalent to MLE and hence the results depend on the numeraire. This problem is related to the difficulties previously mentioned in using the alternative weighting matrix in obtaining efficient estimates, and is a topic for further research. Pagan and Robertson (1997) provide further information about the types of problems which can arise with GMM estimation - unfortunately it seems neither easy nor clear cut to establish the particular source of difficulty in any given problem.

Examination of the variance decompositions leads to several generalisations about the nature of the currencies examined. The currencies tend to fall into three groups. In the first group - comprising the US dollar, the Canadian dollar, the German mark and the Swiss franc the proportion of volatility in exchange rates against these currencies accounted for by domestic factors is relatively small (although no measures of precision have been calculated). For the Japanese yen and the British pound a more notable contribution to volatility is made by domestic factors. Finally, volatility in exchange rates involving the Australian dollar seems to most widely reflect domestic factors. Some further cross categorisation occurs within these groups - exchange rates involving the DEM or CHF tend to have a relatively large contribution from world factors and exchange rates involving the UK pound or Japanese yen tend to divide the 'non-domestic' factor contribution relatively evenly between world and other country factors.

4. Conclusion

The attempt in this paper to classify sources of exchange rate volatility presents some interesting conclusions. The results indicate that, when looking to understand volatility in exchange rates the factors involved can differ across currencies. The factor contributions suggest that in looking to understand the influences on volatility in Australian dollar exchange rates uniquely Australian factors are a greater influence than international events. In the case of the British pound and Japanese yen, volatility in exchange rates against these currencies seems to be influenced by both domestic and international sources, while the US dollar, Canadian dollar, Swiss franc and German mark results all indicate that a unique domestic factor is relatively unimportant in explaining exchange rate volatility against these currencies. These results suggest that one of the reasons for lack of success in identifying consistent sources of volatility across different exchange rates is that the sources of exchange rate volatility themselves differ dramatically across different currencies. The 'news' events which affect different currencies combine to form a complex reaction in bilateral exchange rates, which is further complicated by the reactions of those exchange rates to world events. This would suggest that the results of examining the influence of common factors, such as specific news releases, across a panel of exchange rates will depend to a large extent on the particular currencies chosen for the panel, which may go someway to explaining the lack of consensus in the results of studies on the effect of 'news' on exchange rate volatility.

References

Boulton, L.F., Dungey, M.H. and Parkin, M.B. (1991) "Volatility of the Australian Dollar Exchange Rate" *Journal of Foreign Exchange and International Finance* 5 (3) pp.207-15

BIS (1992) Survey of Foreign Exchange Market Activity, Basle

Collinge R.A. (1994) "Dampening Exchange Rate Volatility: A Micro Alternative to Macro Policies" *Journal of Policy Modelling* 16 (1) pp.113-118

Dungey M. (1997) "A Multilateral Approach to Decomposing Volatility in Bilateral Exchange Rates" Australian National University Working Papers in Economics and Econometrics No. 320

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

Frankel J.A. and K.A. Froot (1987) "Using Survey Data to Test Standard Propositions Regarding Exchange Rate Expectations" *American Economic Review* 77 (1) pp.133-53

Greene W. (1993) Econometric Analysis 2nd ed. MacMillan, Toronto

Hamilton J.D. (1994) Time Series Analysis Princeton University Press, Princeton

Hansen L.P. (1982) "Large Sample Properties of Generalized Method of Moments Estimators" *Econometrica* 50 (4) pp.1029-54

Hasan S. and M. Wallace (1996) "Real Exchange Rate Volatility and Exchange Rate Regimes: Evidence from Long-Term Data" *Economics Letters* 52 (1) pp.67-73

Hogan K.C. and M.T. Melvin (1994) "Sources of meteor showers and heat waves in the foreign exchange market" *Journal of International Economics* 37 pp.239-47

Koedijk K.G. and C.C.P. Wolff (1996) "Exchange rate returns, 'news', and risk premia" *Economics Letters* 50 pp.127-34

Mahieu, R. and P. Schotman (1994) "Neglected common factors in exchange rate volatility" *Journal of Empirical Finance* 1 pp.279-311

Melvin M. and K. Tan (1996) "Foreign Exchange Market Bid-Ask Spreads and the Market Price of Social Unrest" *Oxford Economic Papers* 48 pp.329-41

Newey W. and K. West (1987) "A Simple Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix" *Econometrica* 55 pp.703-8.

Pagan A. and J.Robertson (1997) "GMM and its problems" mimeo, Australian National University

Rao M.J.M. (1993) "Excessive Exchange Rate Volatility: A Possible Explanation Using Chaos Theory" *Journal of Foreign Exchange and International Finance* 7 (3) pp.279-301

Rose A.K. (1994) "Are Exchange Rates Macroeconomic Phenomena?" *Federal Reserve Bank of San Francisco Economic Review* 1 pp.19-30

Sultan J. (1994) "Trade Deficit Announcements and Exchange Rate Volatility: Evidence from the Spot and Futures Markets" *The Journal of Futures Markets* 14 (4) pp.379-404