Implications of news asymmetries in foreign exchange markets

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Abstract

We employ a multivariate BEKK GARCH model that allows news to affect the conditional volatility in an asymmetric manner. The asymmetric model outperforms the standard BEKK implying that efficient financial decision makers should not treat good and bad news as homogenous. We estimate the conditional variances and covariances of the Japanese yen, Swiss franc and British pound *vis-à-vis* the US dollar over a long time series from January 1971 to June 2005. We find evidence of significant spillover effects across markets which are determined by the type of news arriving in the markets. Analysing the dynamics of exchange rate volatility, we find conditional volatilities, covariances and correlations between exchange rates to be time varying.

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1. Introduction

This paper examines the exchange rate dynamics of three leading currencies *vis-à-vis* the US dollar from 1971 to 2005 and during which time the dollar was floating. Specifically, we estimate exchange rate volatility and use these estimates to calculate the conditional covariance and correlation between currencies. Establishing the dynamics of exchange rate returns and their comovements are important for the purposes of risk management; asset pricing and asset allocation; international trade; and economic and exchange rate management. Imprecise measurement which does not take into account heteroskedasticity is likely to render inefficient financial decision making.

An important issue in the exchange rate literature is how markets react to news. In studies of market microstructure and exchange rate volatility – which tend to employ intra day data - news is classified either as public or private news with public news referring mainly to [scheduled and unscheduled] announcements about macroeconomic events. Private news maybe divided into unreleased information held by public bodies like central banks, and private information held by traders.[1] There are several studies of the effects of news announcements in the literature; for instance, on the Euro-dollar market (Omrane et al, 2003), the Norwegian krone (Bauwens et al, 2005), the yen-dollar market (DeGennarro and Shrieves, 1997; Melvin and Yin, 2000; Andersen et al, 2003); the deutschemark-dollar market (Andersen and Bollerslev, 1998; Daníelsson and Payne, 2002; Andersen et al, 2003). A general finding of these studies is that scheduled news announcements and time-of-the-day effects are found to be important variables in predicting exchange rate changes.

A recent paper by Evans and Lyons (2005) finds the information content of news does not decay as quickly as suggested in the above. Whilst foreign exchange markets do respond quickly to news, the effects of this news persists as market participants adjust their positions *vis-à-vis* their prior expectations. Given this finding, we estimate exchange rate volatility over a long time series and quantify news effects. We consider the volatility transmission process and identify the extent to which volatility can be predicted by news originating in one specific exchange rate market, and by news originating in other currency markets, so-called spillover effects. It is an empirical issue whether asset returns are conditional upon news originating in the home market or upon news originating in foreign markets. These hypotheses are referred to as the heat wave and meteor shower (see Engle et al, 1990; Ito et al, 1992). The seminal literature finds that exchange rates display similar features to equities: namely, volatility clustering, persistence, skewness, kurtosis, as well as spillovers or volatility transmission between markets.[2]

[1] Humpage (2003) notes that central banks sometimes operated in secret during the 1970s and 1980s. This was because central banks wanted to convince the market that the observed changes inmarket activity emananted from the private sector.

[2] See Engle and Bollerslev, 1986; Boothe and Glassman, 1987; Hsieh, 1989; Baillie and Bollerslev, 1989, 1990; Bollerslev and Engle, 1993; Engle et al, 1990; and Ito et al, 1992. Generally, these studies examine volatility transmission between the US dollar and the currencies of other industrial nations.

Whereas several studies investigate volatility transmission, most studies treat news as symmetrical. Failure to account for asymmetric responses to good and bad news can lead to model mis-specification. The importance of modelling asymmetry in the transmission of volatility is noted by Nelson (1991), Engle and Ng (1993), Glosten et al (1993), Bekaert and Harvey (1997), Brooks and Henry (2000), and Bekaert et al (2003). Kroner and Ng (1998) define the asymmetric volatility effect as implying that bad news shocks lead to higher volatility than good news shocks. This occurs because there is an increase in information following the announcement of bad news which will affect the covariance between returns. The transmission of news, and its processing and interpretation, is important because it conditions the expectations of market participants, which in turn influences the volatility of returns in a continual process.[3]

There are reasons to expect an asymmetric response to the arrival of new information. Evans and Lyons (2004) claim that [private, short-term] trading explains exchange rate volatility more than public macro news concerning economic fundamentals. According to Evans and Lyons, the short-term impact of public macro news is minimal because the aggregation of prior micro news regarding market transactions is likely to render macro news redundant. Whilst Evans and Lyons report empirical evidence of a medium-term to long-term effect of macro news on exchange rate volatility – because of the so-called embedding effect[4] – there is evidence to the contrary. Andersen and Bollerslev (1998) find the largest returns to be positively related to macro news announcements – about economic and trade fundamentals in the US and monetary aggregates in Germany. Asymmetric dependence in - the deutschemark-dollar(DM, hereafter) and yen-dollar - exchange rates may be explained by central bank management of the exchange rate (Patton, forthcoming). Should the DM depreciate against the US dollar, the Bank of Japan may manoeuvre a corresponding depreciation of the yen against the dollar in order to protect the competitiveness of Japanese exports to the US with German exports to the US. Should the DM appreciate against the dollar, the Bank of Japan would be less likely to appreciate the yen against the dollar. Another reason concerns the re-balancing of currency portfolios. The strengthening of the dollar is often accompanied by a shift of funds from other currencies into the dollar; a weakening of the dollar see much of these funds shift into the DM or euro, rather than the yen, as the former was/is the second most important currency.

Researchers identify two types of asymmetries: in individual returns; and in the dependence between returns. Asymmetries are found in different types of asset returns: stock returns (see Kroner and Ng, 1998), optimal hedge ratios (Brooks et al, 2002), and exchange rate returns (Patton, forthcoming). The covariance of country returns with returns on the world stock market – an indicator of country risk – shows an asymmetric

[3] A voluminous literature considers whether private or public information is the more important channel of transmission. For instance, future changes in exchange rates cannot be predicted using publicly available information because rates follow a martingale process. When news arrives, market participants process the new information often with reference to earlier priors which could be based on private information. It is these market dynamics that lead to a continuation of volatility (Engle et al, 1990).

[4] The embedding effect occurs because the market absorbs and processes macro news gradually which causes rational exchange rate errors in portfolio allocations (Evans and Lyons, 2004).

response to the arrival of new information, which will distort portfolio decisions and diversification effects unless asymmetry is accounted for (Henry et al, 2004). Asymmetric information effects are also found in macroeconomic variables like inflation which affect the rate of output growth (Shields et al, 2005; Grier et al, 2004). An asymmetric dependence between returns implies that correlations between returns are larger during episodes of financial distress compared to periods of relative stability (Patton, 2004; Hong et al. 2004).

Empirical evidence suggests volatility responds asymmetrically to changes in exchange rate regimes. Bollerslev (1990) compares the volatility of five European exchange rates *vis-à-vis* the US dollar before and after the creation of the EMS (European Monetary System) in March 1979; in other words, after an increase in policy coordination.[5] Similarly, Laopodis (1998) examines volatility transmission between three EMS and three non-EMS exchange rates *vis-à-vis* the German mark before and after the unification of Germany in 1990.[6] Bollerslev (1990) finds that exchange rate volatility and conditional covariances between exchange rates increase after the creation of the EMS. On the contrary, formerly significant spillover effects between EMS currencies disappear after German unification whereas volatility persistence actually increases for non-EMS currencies. Laopodis (1998) also finds evidence of asymmetric behaviour in the volatility transmission process. Other empirical evidence concerning the transmission of volatility from the German mark to other EMS currencies is found in Kearney and Patton (2000).

In this paper, we model the conditional volatility of three exchange rates: namely, the Japanese yen, the Swiss franc, and the British pound all *vis-à-vis* the US dollar from 4th January 1971 to 30th June 2005. By using a lengthy time series of daily exchange rate data, we aim to model the effects that short-run movements have on exchange rate volatility. The period is noteworthy in the context of economic history. It begins with the collapse with the Bretton Woods fixed exchange rate system and the implementation of flexible exchange rate regimes. The period is also characterised by changes in monetary targeting, participation in other fixed exchange rate regimes, currency and financial crises, economic stagnation, the bursting of asset price bubbles, and exogenous shocks such as the Oil Crises of 1973 and 1979.

Our main objective is to model exchange rate returns with news being allowed to enter the markets in an asymmetric manner. The preferred model is the multivariate GARCH BEKK which estimates volatility and quantifies the impact of domestic and cross-border news arrivals on the conditional variance of exchange rate returns. Thus, we can determine to what extent exchange rates are affected by the heat wave and meteor shower

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5 The EMS currencies are the French franc, German mark and Italian lira whilst the other European currencies are the British pound and Swiss franc. The pre-EMS period runs from July 1973 to March 1979 and the post EMS period from March 1979 to August 1985, thereby allowing for a comparison of volatilities under floating and fixed exchange rate regimes (see Bollerslev, 1990).

6 The EMS currencies are the Belgian franc, Dutch guilder, and French franc; and the non-EMS currencies the Canadian dollar, Japanese yen, and US dollar. The period of analysis covers March 13th, 1979 to December 30th, 1996. In order to investigate the effects of German reunification, two sub-samples are created: from March 13th 1979 to June 30th, 1990; and July 1st 1990 to December 30th, 1996. The data exclude exchange rate realignments and speculative attacks (see Laopodis, 1998).

hypotheses. Due to difficulties estimating multivariate asymmetric GARCH models, there are few studies that have employed this methodology. The model specification allows us to determine the following cross-market asymmetric transmission effects on volatility: first, on days when the dollar is appreciating against each [depreciating] currency; second, on days when the dollar is appreciating against the yen but depreciating against the franc and pound; and third, on days when the dollar is depreciating against the yen and appreciating against the franc and pound. We consider the dynamics of volatility in exchange rate returns by calculating the conditional covariance and correlation between currencies and examining whether the two measures, and exchange rate volatility, are time-varying.

2. Model Specification

A wealth of literature is devoted to modelling temporal dependence in the second order moments of asset returns. The seminal works are Engle (1982) and Bollerslev (1986) which presented the ARCH and GARCH methodologies. A multitude of methodological developments and empirical applications have emerged since.[7] We estimate a multivariate GARCH using the BEKK[8] model of Engle and Kroner (1995), where the restriction of a symmetrical variance-covariance structure is removed and news is allowed to behave in an asymmetric manner following Glosten et al. (1993). Thus, the paper contributes to a limited set of studies which estimate asymmetric GARCH models in applications to stock market volatility and spillovers (Ng, 2000), optimal hedge ratios (Brooks et al., 2002), asset returns (Kroner and Ng, 1998), and stock and bond returns (De Goeij and Marquering, 2004).

Let r_t equal the continuously compounded return on a currency exchange rate over the period t–1 to t. The information set available to investors at time t–1, when investment decisions are taken, is denoted Ω_{t-1}. The expected return and volatility of returns based on those decisions are the conditional mean and variance of r_t given Ω_{t-1}, denoted $y_t = E(r_t \mid \Omega_{t-1})$ and $h_t = var(r_t \mid \Omega_{t-1})$, respectively. The unexpected return at time t is $\varepsilon_t = r_t - y_t$. Following Engle and Ng (1993), ε_t can be interpreted as a measure of news. An unexpected increase in returns ($\varepsilon_t > 0$) indicates the arrival of good news, whilst an unexpected decrease in returns ($\varepsilon_t < 0$) indicates bad news.

The conditional variance h_t may be modelled as a function of the lagged ε_t, implying that predictable volatility is dependent on past news, with the effect of any piece of news upon current volatility decreasing as the news becomes older or decays (Engle, 1982). In the GARCH specification introduced by Bollerslev (1986), the effect of a shock to returns decreases geometrically over time. In its simplest form, the univariate GARCH(p,q) model may be specified as follows:

[7] For excellent reviews of theoretical developments in modelling conditional heteroskedasticity and associated empirical evidence, see Bollerslev et al (1992) and Bauwens et al (2003).

[8] BEKK stands for Baba, Engle, Kraft and Kroner.

$$h_t = \omega + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j h_{t-j} \quad [1]$$

where $\omega > 0$; $\alpha_1, \ldots, \alpha_p \geq 0$; and $\beta_1, \ldots, \beta_q \geq 0$ are constant parameters, and the non-negativity conditions ensure the conditional variance is positive. Equation [1] imposes a restriction of symmetry on the conditional variance structure. This restriction is undesirable in view of the *a priori* assumption that markets do not treat good and bad news, or small and large news shocks, in an equal manner. For an asymmetric effect, the impact of a shock of any given magnitude on the covariance equation differs depending upon whether the shock is positive (good news) or negative (bad news).

Following Glosten et al. (1993), equation [1] can be re-specified to account for the possibility of asymmetric effects. Let $k_{t-1}=1$ if $\varepsilon_{t-1}<0$, and $k_{t-1}=0$ otherwise. For ease of exposition we assume p=q=1, or a GARCH(1,1) specification:

$$h_t = \omega + (\alpha + \delta k_{t-1})\, \varepsilon_{t-1}^2 + \beta h_{t-1} \quad [2]$$

$\delta>0$ implies a bad news shock has a greater impact on volatility than a good news shock. The conditions $\omega>0$, $\alpha\geq0$, $\alpha+\delta\geq0$ and $\beta\geq0$ must be satisfied in order to ensure a positive conditional variance.

For a multivariate model, let $r_{m,t}$ denote the continuously compounded return on the m'th country's exchange rate over the period t–1 to t, for m=1 ... M. The expected return is the conditional mean of $r_{m,t}$ given Ω_{t-1}, denoted $y_{m,t} = E(r_{m,t} \mid \Omega_{t-1})$. The unexpected return at time t is $\varepsilon_{m,t} = r_{m,t} - y_{m,t}$. As before, the conditional variance-covariance matrix is measurable with respect to the information set, Ω_{t-1}, such that $\varepsilon_t \mid \Omega_{t-1} \sim N(0, H_t)$, where ε_t is an M×1 vector containing $\{\varepsilon_{m,t}\}$ for m=1 ... M, and H_t is an M×M matrix containing the conditional variances and covariances for the disturbance terms of the M equations.

We express the multivariate counterpart of equation [1] using the GARCH-BEKK specification, which guarantees that H_t is positive-definite through the imposition of quadratic forms upon the matrices of coefficients:

$$H_t = C'C + \sum_{i=1}^{p} A_i \varepsilon_{t-i} \varepsilon_{t-i}' A_i' + \sum_{j=1}^{q} B_j H_{t-j} B_j' \quad [3]$$

C is an M×M upper-triangular matrix of coefficients, and A_i and B_j are (unrestricted) M×M matrices of coefficients. The GARCH-BEKK specification permits the estimation of spillover effects between equations. One drawback of [3], however, is it implies that only the magnitude of previous news is important in determining the current conditional variances and covariances. This is excessively restrictive because it does not allow for the very real possibility of asymmetric effects, defined as before. For a multivariate model, these can be specified as follows.

Let $K_{1,t-1}$ = a 3×3 identity matrix if $\varepsilon_{1,t-1}<0$, $\varepsilon_{2,t-1}<0$ and $\varepsilon_{3,t-1}<0$, or a 3×3 matrix of 0's otherwise. Similarly, let $K_{2,t-1}$ = a 3×3 identity matrix if $\varepsilon_{1,t-1}<0$, $\varepsilon_{2,t-1}<0$ and $\varepsilon_{3,t-1}>0$, or a 3×3 matrix of 0's otherwise; and let $K_{3,t-1}$ = a 3×3 identity matrix if $\varepsilon_{1,t-1}>0$, $\varepsilon_{2,t-1}<0$ and $\varepsilon_{3,t-1}<0$, or a 3×3 matrix of 0's otherwise.

Let $\xi_{p,t-1} = K_{p,t-1}\varepsilon_{t-1}$ for p = 1 ... 3. As before, for ease of exposition we assume a GARCH(1,1) specification (p=q=1):

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon_{t-1}'A' + D\xi_{1,t-1}\xi_{1,t-1}'D' + E\xi_{2,t-1}\xi_{2,t-1}'E' + F\xi_{3,t-1}\xi_{3,t-1}'F' + BH_{t-1}B' \quad [4]$$

In [4], D, E and F are the matrices of coefficients for the asymmetric effects. Since the symmetric and linear GARCH-BEKK model (i.e. [3] with p=q=1) is a restricted version of [4] in which D = E = F = 0, a likelihood ratio test can be used to determine the more appropriate model specification.

In the estimations that are reported below, the number of equations is M=3. We let $r_{m,t}$ denote the continuously compounded returns for the Japanese yen-US dollar rate (m=1), the Swiss franc-US dollar rate (m=2), and the British pound-US dollar rate (m=3).

3. Data Description

The data employed in this study comprise 8,998 daily observations on three exchange rates from January 4th, 1971 to June 29th, 2005. The exchange rates are *vis-à-vis* the US dollar and the currencies are the Japanese yen, Swiss franc, and British pound. The data are the H.10 Foreign Exchange Rate series that are produced by the Board of Governors of the Federal Reserve System in the US. The exchange rates are noon buying rates in New York for cable transfers payable in foreign currencies.

Figure 1 shows the evolution of the exchange rates and the returns over time. The return series are calculated as 100 x $ln(R_t / R_{t-1})$ where R is the exchange rate at time *t*. In the left hand side of Figure 1 we observe different patterns in exchange rate movements. Generally speaking, the US dollar depreciates following the collapse of the fixed exchange rate system in 1971 until the late 1970s. Short sharp dollar depreciation takes place in the mid-to-late 1980s which is followed by a more gradual depreciation to the mid 1990s. Rates appear relatively stable during the past decade. The Japanese yen appreciated against the dollar between 1971 and 1978 and was followed by a gradual depreciation of the yen from 1978 to 1985. Thereafter, the yen appreciates from around ¥250:$ towards its highest value at around ¥80:$ against the dollar in 1995. Although the yen gradually depreciated after 1995, the yen-to-dollar rate is relatively stable. Similar to the yen, the Swiss franc appreciated considerably against the dollar from 1971 to 1978 though the dollar wiped out around 50% of the earlier franc appreciation during the early to mid 1980s. The franc reversed this trend between 1985 and 1987 and it has remained relatively stable to the present. On the contrary, the British pound depreciated against the dollar in two intervals over 1971 to 1985; between 1971 and 1976, and 1981 to 1985 (which followed an appreciating pound circa 1977 to 1980). Another large appreciation of the pound occurred over 1985 to 1988 after which its relationship with the dollar was less volatile. The pound has been allowed to float since it left the European exchange rate mechanism in September 1992. Since then, the pound has been relatively stable against the dollar although it is strengthening from around 2001 to the present.

Figure 1 here

The returns are shown in the right hand side of Figure 1. Each series displays evidence of unpredictability and volatility clustering. These features are established by looking at the autocorrelation of returns and squared returns. If returns are predictable, the autocorrelations should be significant, whilst volatility clustering will appear as significant autocorrelations in the squared returns. Table 1 shows the return autocorrelations to be insignificant and the squared returns autocorrelations to be significant.

Table 1 here

The Ljung-Box Q statistic is calculated at various lag lengths from 6 to 30 days for the returns and squared returns series. For the returns series, a significant Q statistic rejects the null hypothesis of no serial correlation in returns, whilst a significant Q statistic for the squared returns series rejects the null hypothesis that squared returns are homoskedastic. Table 2 shows the Q statistics to be significant at different lags across each currency market. Thus, the returns series are characterised by the presence of higher order serial correlation and the non randomness of returns, and the squared returns series display non-linear dependency. The findings of autocorrelation, higher order serial correlation, and non-linear dependency support the decision to model exchange rate volatility using a GARCH model.

Table 2 here

Table 3 presents some descriptive statistics of the returns series. The sample means show the yen and franc with small negative, significant returns of around one-seventy fifth of a percent per day. The mean return on the pound is positive and insignificant at just under one-three hundredths of a per cent per day. The daily variances are 0.3977, 0.514, and 0.33, for the yen, franc, and pound. Expressing these data as average annualised volatilities, the franc is the more risky currency with an annualised volatility of 11.38% compared to 10.01% and 9.12% for the yen and pound, respectively. The distributional features of the returns series are as expected. The null hypothesis of normally distributed returns is convincingly rejected by the Jarque-Bera statistics and the data are skewed; yen returns have a negative skew whereas franc and pound returns are positive. Kurtosis is a measure of the extremes compared with what would be expected from a normal random variable. If returns are normally distributed, then the kurtosis coefficient should be three. The kurtosis coefficient is greater than three for each currency. However, returns on the yen are much more extreme than returns on the franc and yen as illustrated by its kurtosis coefficient of nearly 12. Extreme kurtosis indicates the currency returns are fat tailed.

Table 3 here

4. Empirical Results

Diagnostic Tests of Model

We estimate the standard BEKK and asymmetric BEKK models using a GARCH(1,1) approach. The number of optimal lags to be used in the returns model was determined by the Schwartz Information Criterion. The BFGS (Broyden, Fletcher, Goldfarb, and Shanno) algorithm is used to maximise the log likelihood function. We adopt the quasi-maximum likelihood estimation (QML) of Bollerslev and Wooldridge (1992), which allows inference when the conditional distribution of the residuals is non-normal. Convergence is achieved is 73 iterations and 129 iterations for the standard and asymmetric models, respectively. The selection of the preferred model specification is based on a likelihood ratio test of the null hypothesis that $\delta_{m,n} = \lambda_{m,n} = \gamma_{m,n} = 0$. The likelihood test statistic equals 846.23, which exceeds the critical value of 49.6449 from the $\chi^2_{0.005}$ distribution. This implies the null hypothesis is strongly rejected by the data and suggests that modelling asymmetric news is important in predicting the volatility of exchange rates, which could yield an advantage to market participants.

Table 4 shows the distributional features of the residuals. The standardised residuals are skewed and have heavy tails implying that they are not normally distributed *iid* standard normal variables. The specification of the model in terms of adequately capturing the dynamics of the data is checked by testing the standardised residuals for the presence of serial correlation and heteroskedasticity. If the model is correctly specified, the standardised residuals will be *iid* standard normal variables. Typically, univariate tests are applied independently to each series although multivariate tests are also applied (see, Kroner and Ng, 1998; Ding and Engle, 2001). We follow the former approach and carry out independent residual diagnostic tests using the Ljung-Box test and the residual ARCH test (see Engle, 1982).

Table 4 here

Ljung-Box Q statistics are calculated on the standardised residuals (ε_1, ε_2, ε_3), standardised squared residuals ($\varepsilon^2{}_1$, $\varepsilon^2{}_2$, $\varepsilon^2{}_3$), and cross-products of residuals ($\varepsilon_1\varepsilon_2$, $\varepsilon_2\varepsilon_3$, $\varepsilon_2\varepsilon_3$). The Q statistics are calculated at different lag lengths and they are a test for the presence of higher order serial correlation in the standardised residuals. However, the null hypothesis of no serial correlation in the standardised residuals is not accepted by the data but it is accepted in their cross-products (with one exception). Arguably, it is unreasonable to expect the model to completely account for serial correlation since the daily returns are highly leptokurtic. The model adequately captures all of the persistence in the variance of returns since the standardised squared residuals are serially uncorrelated. There is no evidence of residual ARCH effects in the residuals. Our final diagnostic follows De Goeij and Marquering (2004) and tests the null hypothesis that the means of the standardised residuals are significantly different to zero, and the means of the standardised squared residuals and cross-products are significantly different from unity. Whilst we cannot accept that the means of the standardised residuals are not significantly different from zero (there is one exception), the data do not reject the null that the means of the standardised squared residuals and the cross-products are significantly different from unity. According to De Goeij and Marquering, the latter set of results satisfies requirements for consistency in the QML estimates.

Volatility transmission and the effect of asymmetric news

The BEKK model shows the persistence of volatility following innovations in the returns to an asset. We treat the innovations as the continual arrival of news to which the currency markets respond by adjusting the prices of currencies in line with their *a priori* expectations. Markets respond to their own news and news from other markets. The latter is known as spillover effects or volatility transmission in the literature. The BEKK model estimates coefficients which quantify the impact on the conditional variance of a currency of news originating in that particular currency market as well as other currency markets. The estimated coefficients for the asymmetric BEKK model are shown in Table 5.

Our first task is to discuss the coefficients of matrix A in equation [4] which are denoted by α_{mn}. These are coefficients on the lagged squared error terms which provide the innovations in each market. News from each individual currency market is considerably more important in predicting foreign exchange volatility than news arriving about other currencies. The coefficients α_{11}, α_{22}, and α_{33}, quantify the impact of news in the yen-dollar, franc-dollar, and pound-dollar markets, respectively, and each coefficient is greater than 0.9 and highly significant. There is evidence of some significant spillover effects although the magnitude of these coefficients are very small compared with the own market coefficients. It would appear that the conditional variance of returns in the yen is affected by the arrival of news concerning the pound and vice-versa (α_{13} and α_{31}). The conditional volatility of the yen is also responsive to news about the franc (α_{12}), whereas the volatility of the franc is part determined by news of the pound (α_{23}).

The coefficients in matrix B indicate the persistence of news or the rate at which news decays. The level of news persistence in a market is greater when news emanates from that market. The coefficients β_{11}, β_{22}, and β_{33}, are much larger than the cross-market coefficients. The coefficients imply that the effect of the arrival of news from the own market lasts for at least one day with the stronger persistence being observed in the market for yen (β_{11}). News about the franc and pound does not decay for at least one day in the yen market (β_{12} and β_{13}) whereas news about the yen does not decay in the market for pounds (β_{31}).

We consider three types of asymmetric news event. The first type of news event is when the dollar depreciates against every other [appreciating] currency. Matrix D contains a set of coefficients which quantify the effect on conditional volatility of innovations in news on days when returns to each currency are negative. Several interesting features emerge.

News in the Japanese market about a depreciating dollar significantly increases the variance of returns on the [appreciating] yen (δ_{11}) whereas news originating in the UK has the opposite effect on the conditional variance of returns on the [appreciating] pound (δ_{33}). Surprisingly, there is not a significant own market effect on the franc (δ_{22}). The magnitude of the spillover effects in matrix D is much larger than in matrix A. News arriving in Japan from about the Swiss and British exchange rates significantly increases volatility on the yen (δ_{12} and δ_{13}, which are over 0.1 in magnitude). On the contrary, news arriving from Japan about the [appreciating] yen significantly lowers the conditional volatilities of the franc and pound, respectively (δ_{21} and δ_{31}).

The second type of news event occurs on days when the dollar appreciates against the [depreciating] pound and depreciates against both the [appreciating] yen and franc. The own market effect is greater for pounds with the appreciating dollar [depreciating pound) resulting in an increase in the volatility of returns on the pound (λ_{33}). There are a number of bi-lateral spillover effects; for instance, news originating in the markets for francs and pounds raises the conditional variance of returns on the yen (λ_{12} and λ_{13}), and news about the appreciating yen raises conditional volatilities on the franc and pound (λ_{21} and λ_{31}), respectively. A positive bi-lateral relationship is observed between the franc and pound (λ_{23} and λ_{32}). The final type of news event takes place on days when the dollar appreciates against the [depreciating] yen and depreciates against the [appreciating] franc and sterling. This news event produces only minimal spillover effects. For instance, news originating in Japan about the depreciating yen lowers the conditional variance of returns on the yen (γ_{11}). News arriving in Switzerland from Japan serves to lower volatility on franc returns (γ_{21}) whilst news from the Swiss currency market helps to lower the variance of returns on the pound (γ_{32}).

Volatility dynamics

In Figures 2 to 4, we show the evolution of annualised conditional volatility, and the conditional covariance and conditional correlation between each currency from January 1971 to June 2005. Establishing the dynamics of returns and their comovements are important for the purposes of risk management, asset pricing and asset allocation. It is suggested that increasing financial integration and contagion have led to increasing correlation between markets over time. As a result, portfolio risk may be increasing and it is becoming more difficult to optimally allocate assets because diversification is less efficient. These issues are discussed in detail by Forbes and Rigobon (2002), Longin and Solnik (2001), Goetzmann et al (2001), and Boyer et al (1999). For present purposes, we note a conclusion of this literature that it is important to estimate more precise, or conditional, measures of association between markets or asset returns that account for heteroskedasticity in the data.

Figure 2 here

The conditional variances are shown in Figure 2. The annualised mean volatility is similar for each currency: 11.21% for the yen, 11.76% for the franc, and 9.68% for the pound. The annualised mean variance is lower for the franc at 6.27% and similar for the yen and pound at 9.67% and 9.68%, respectively. The patterns show conditional volatility to be time-varying. Volatility appears to be trending upwards from the 1970s to mid-1980s; thereafter, it appears relatively stable with a slight downward pattern. Figure 3 shows the conditional covariances vary over time and they increase during episodes of crisis; for instance, the 1973 oil crisis, the 1987 stock market crash, and the 1997-98 East Asian crisis. On an annualised basis, the mean conditional covariance is marginally higher for the franc and pound at 8.58% compared with 8.36% for the yen and franc. The mean yen-pound covariance is 6.57% and it has the lowest annualised variance at 3.31%.

Figure 3 here

It is possible that the time variation observed in the covariances is due to the variance of volatility. If this is the case, the correlation between currencies will be constant. This is not the case since Figure 4 shows that the conditional correlations are highly variable over time. Generally speaking, correlations between currencies increase until the end of the 1980s where they appear to be at their highest. Over the first half of the 1990s, correlations tend to weaken before strengthening again from around the time of the East Asian crisis. The mean correlation is highest for the franc and pound at 0.5932, followed by the yen and franc and yen and pound at 0.4999 and 0.3623, respectively. The level of annualised variance in correlations is highest for the yen and pound at 3.84% followed by the franc and pound, and yen and franc at 3.45% and 3.3%, respectively.

Figure 4 here

5. Conclusion

In this paper, we employed a multivariate asymmetric BEKK GARCH model to estimate the conditional volatility and volatility dynamics of exchange rate returns between 1971 and 2005. The asymmetric model is superior to the standard model which implies that markets do respond differently to good and bad news, and that these asymmetries should be specified if market participants are to make efficient financial decisions.

An exchange rate market responds more to its own news than it does to news arriving from other exchange rate markets. This suggests exchange markets behave according to the heat wave hypothesis although there is evidence of cross-market spillover effects – the meteor shower. However, in considering the impact on volatility of different types of asymmetric news, the spillover effects increase in magnitude and the home market effect diminishes somewhat. On days when the dollar depreciated against each currency, the volatility of returns in the yen market rose suggesting that higher returns could be made, whilst the opposite effect occurred in the pound exchange rate. On days when the pound depreciated against the dollar, and the franc and yen appreciated the volatility of returns on the pound increased. Finally, on days when the yen appreciated against the dollar, and the franc and pound depreciated the volatility of returns on the yen decreased. In each case, there is evidence of significant cross-market spillover effects.

The dynamics of volatility were established. Conditional volatility, covariances and correlations were found to be time-varying. Generally speaking, there is a sharp upward trend in conditional volatility and correlation from 1971 to the mid-to-late 1980s which probably reflects the increasing integration in financial markets. Although there is variability in the 1990s, the trend is slightly downwards. It is increasing, however, in the early-to-mid 2000s though the patterns show far less dispersion compared with the 1970s and 1980s. We find that the time variation observed in the conditional covariances are not caused by the variance of volatility.

Table 1: Autocorrelations of Returns & Squared Returns

	Returns			Squared Returns		
Lag (days)	**¥ / $**	**SF / $**	**£ / $**	**¥ / $**	**SF / $**	**£ / $**
1	0.0274	0.0172	0.0498	0.0919*	0.1556*	0.1251*
2	0.0230	-0.0041	0.0099	0.0744*	0.1454*	0.1281*
3	0.0012	-0.0009	-0.0118	0.0446*	0.0969*	0.1137*
4	-0.0005	0.0067	0.0040	0.0301*	0.0737*	0.1298*
5	0.0141	0.0067	0.0380	0.0429*	0.0960*	0.1111*
6	-0.0072	-0.0050	-0.0105	0.0450*	0.0743*	0.1281*
7	0.0066	0.0034	-0.0098	0.0280	0.0903*	0.0929*
8	0.0148	0.0168	0.0059	0.0288	0.0730*	0.0848*
9	0.0155	0.0072	0.0198	0.0462*	0.0469*	0.0734*
10	0.0444	0.0172	0.0086	0.0304*	0.0587*	0.1086*
11	0.0060	0.0072	-0.0051	0.0332*	0.0933*	0.1430*
12	0.0060	-0.0081	-0.0121	0.0238	0.0669*	0.0896*
13	0.0052	-0.0079	-0.0112	0.0292	0.0535*	0.0761*
14	0.0133	0.0105	0.0051	0.0409*	0.0739*	0.0959*
15	0.0076	0.0266	0.0314	0.0278	0.0339*	0.0950*
16	0.0042	-0.0001	-0.0056	0.0139	0.0388*	0.0949*
17	-0.0120	-0.0030	0.0092	0.0212	0.0373*	0.0820*
18	0.0159	-0.0097	-0.0102	0.0393*	0.0464*	0.0780*
19	0.0001	0.0031	-0.0055	0.0449*	0.0602*	0.1126*
20	0.0193	0.0122	0.0194	0.0424*	0.0689*	0.1286*
21	0.0069	0.0272	0.0097	0.0330*	0.0465*	0.0572*
22	-0.0018	-0.0072	0.0064	0.0286	0.0413*	0.0766*
23	0.0021	0.0136	0.0148	0.0420*	0.0501*	0.0711*
24	-0.0079	0.0212	0.0016	0.0337*	0.0345*	0.0562*
25	0.0202	0.0082	0.0204	0.0265	0.0508*	0.0879*
26	0.0018	-0.0201	-0.0118	0.0333*	0.0275	0.0866*
27	0.0023	-0.0029	0.0124	0.0273	0.0357*	0.0513*
28	0.0077	0.0083	0.0163	0.0332*	0.0414*	0.0749*
29	-0.0031	-0.0007	0.0081	0.0261	0.0535*	0.0712*
30	-0.0134	0.0018	0.0082	0.0143	0.0730*	0.0660*

Note: * , statistically significant at the 5 percent level.

Table 2: Descriptive Statistics: Exchange Rate Returns

	¥ / $	SF / $	£ / $
Sample Mean	-0.0129*	-0.0134*	0.0034
Standard Error	0.6306	0.7170	0.5744
Variance	0.3977	0.5140	0.3300
Standard Error of the Mean	0.0066	0.0076	0.0061
t-Statistic (Mean = 0)	-1.9462	-1.7691	0.1594***
Skewness	-0.7798***	0.0006	0.2142***
Kurtosis (excess)	11.7957***	3.8519***	4.4027***
Jarque-Bera	53118.87***	5562.21***	7304.60***
Observations	8997	8997	8997

Note: ***, **, * statistically significant at 1%, 5% and 10%.

Table 3: Ljung-Box Q Statistics (6 to 30 lags) for Returns & Squared Returns

	Returns	Squared returns
¥ / $		
Q (6 lags)	13.79***	186.68***
Q (12 lags)	36.74***	243.81***
Q (18 lags)	42.84***	293.26***
Q (24 lags)	47.26***	371.04***
Q (30 lags)	53.27***	412.01***
SF / $		
Q (6 lags)	3.88**	674.36***
Q (12 lags)	10.67	965.27***
Q (18 lags)	19.54	1096.10***
Q (24 lags)	33.82**	1239.86***
Q (30 lags)	38.82**	1370.86***
£ / $		
Q (6 lags)	38.58***	815.89***
Q (12 lags)	45.51***	1369.68***
Q (18 lags)	57.72***	1782.79***
Q (24 lags)	64.62***	2202.99***
Q (30 lags)	74.61***	2500.02***

Note: ***, **, * statistically significant at 1%, 5% and 10%.

Table 4: Diagnostic Tests: Standardised, Standardised Squared, and Cross-Products of Residuals; Asymmetric BEKK model

	ε_1	ε_2	ε_3	ε^2_1	ε^2_2	ε^2_3	$\varepsilon_1\varepsilon_2$	$\varepsilon_1\varepsilon_3$	$\varepsilon_2\varepsilon_3$
Mean	-0.0218**	-0.0154	0.0206**	0.9910	0.9889	0.9927	1.0192	0.1528	1.1374
Variance	0.9906	0.9888	0.9923	21.3330	7.2576	11.6866	132.69	18468.90	178.6093
Skewness	-1.1135	-0.1666	0.2552	38.7741	21.5263	29.5976	2.8070	-53.1438	46.1962
Kurtosis	19.6528	5.4169	9.8525	2049.0696	855.3001	1374.6869	956.6093	3452.5374	2898.7708
LM ARCH test[(a)]				2.8339	5.2366	1.4751			
t-stat for H_0: $\varepsilon_{it} = 0$	-2.0769	-1.4728	1.9635	-	-	-	-	-	-
t-stat for H_0: $\varepsilon_{it}\varepsilon_{it} = 1$	-	-	-	-0.1848	-0.3915	-0.2039	0.1578	-0.5913	0.9749
Ljung-Box Q Statistics[(b)]									
Q (6)	33.7029***	15.235	35.407***	4.144	5.262	1.736	153.174***	0.147	3.725
Q (12)	66.444***	32.465***	53.420***	7.268	9.256	4.507	163.646***	0.203	5.501
Q (18)	75.775***	39.013**	62.826***	8.900	13.135	8.966	176.248***	0.257	12.263
Q (24)	81.554***	54.113***	72.504***	9.412	44.891**	13.160	210.985***	0.319	13.735
Q (30)	89.493***	59.353***	85.549***	10.387	49.984**	15.892	212.262***	0.513	58.938***

Notes:
(a) The LM ARCH test is the Lagrange multiplier test of Engle (1982) for the presence of ARCH effects in residuals. The 95% and 99% critical values from the χ^2 distribution with *df* = 5 are 11.1 and 16.7, respectively.

(b) The 95% critical values for Q(6), Q(12), Q(18), Q(24), and Q(30) are 12.6, 21.0, 28.9, 36.4 and 43.8, respectively. The 99% critical values for Q(6), Q(12), Q(18), Q(24), and Q(30) are 18.5, 28.3, 37.2, 45.6 and 53.7, respectively.
***, and ** Indicate statistical significance at the 1% and 5% levels, respectively.

Table 5: Multivariate GARCH Results: Standard & Asymmetric BEKK

		Standard BEKK		Asymmetric BEKK	
Variable		**Coefficient**	**Standard error**	**Coefficient**	**Standard error**
C11	ω_{11}	0.0970***	0.0160	0.0047	0.0034
C12	ω_{12}	0.0290***	0.0091	0.0065	0.0375
C13	ω_{13}	-0.0095**	0.0044	-0.0346***	0.0102
C22	ω_{22}	0.0672***	0.0082	0.0749***	0.0078
C23	ω_{23}	-0.0140	0.0093	-0.0046	0.0125
C33	ω_{33}	0.0513***	0.0045	0.0000	0.0005
A11	α_{11}	0.3602***	0.0410	0.9095***	0.0055
A12	α_{12}	0.0692**	0.0299	-0.0180***	0.0037
A13	α_{13}	0.0426	0.0263	-0.0070**	0.0035
A21	α_{21}	-0.0284**	0.0142	0.0006	0.0020
A22	α_{22}	0.2265***	0.0112	0.9549***	0.0032
A23	α_{23}	-0.0266**	0.0124	0.0096**	0.0041
A31	α_{31}	-0.0211	0.0206	0.0097**	0.0042
A32	α_{32}	-0.0027	0.0224	0.0027	0.0016
A33	α_{33}	0.2633***	0.0184	0.9427***	0.0046
B11	β_{11}	0.9289***	0.0146	0.4098***	0.0310
B12	β_{12}	-0.0167*	0.0088	0.0785***	0.0226
B13	β_{13}	-0.0075	0.0066	0.0311**	0.0141
B21	β_{21}	0.0056	0.0048	0.0004	0.0176
B22	β_{22}	0.9654***	0.0038	0.2404***	0.0152
B23	β_{23}	0.0133***	0.0044	-0.0074	0.0138
B31	β_{31}	0.0133**	0.0061	-0.0890***	0.0248
B32	β_{32}	0.0094	0.0065	-0.0042	0.0203
B33	β_{33}	0.9558***	0.0048	0.2615***	0.0248
D11	δ_{11}	-	-	0.2239***	0.0758
D12	δ_{12}	-	-	0.1087***	0.0292
D13	δ_{13}	-	-	0.1043***	0.0168
D21	δ_{21}	-	-	-0.1083***	0.0393
D22	δ_{22}	-	-	-0.0558	0.0623
D23	δ_{23}	-	-	0.0711**	0.0299
D31	δ_{31}	-	-	-0.1815*	0.1061
D32	δ_{32}	-	-	-0.1096	0.0888
D33	δ_{33}	-	-	-0.1724***	0.0484
E11	λ_{11}	-	-	-0.0357	0.0472
E12	λ_{12}	-	-	0.0651**	0.0304
E13	λ_{13}	-	-	0.0789***	0.0261
E21	λ_{21}	-	-	0.1142***	0.0308
E22	λ_{22}	-	-	0.0931***	0.0294
E23	λ_{23}	-	-	-0.0172	0.0207
E31	λ_{31}	-	-	0.0507**	0.0252
E32	λ_{32}	-	-	0.0345*	0.0194
E33	λ_{33}	-	-	0.2159***	0.0383
F11	γ_{11}	-	-	-0.1356**	0.0671
F12	γ_{12}	-	-	-0.0354	0.0723
F13	γ_{13}	-	-	0.0341	0.0578
F21	γ_{21}	-	-	-0.0531*	0.0315

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Figure 1 – Exchange Rate Index and Returns, January 1971 – June 2005

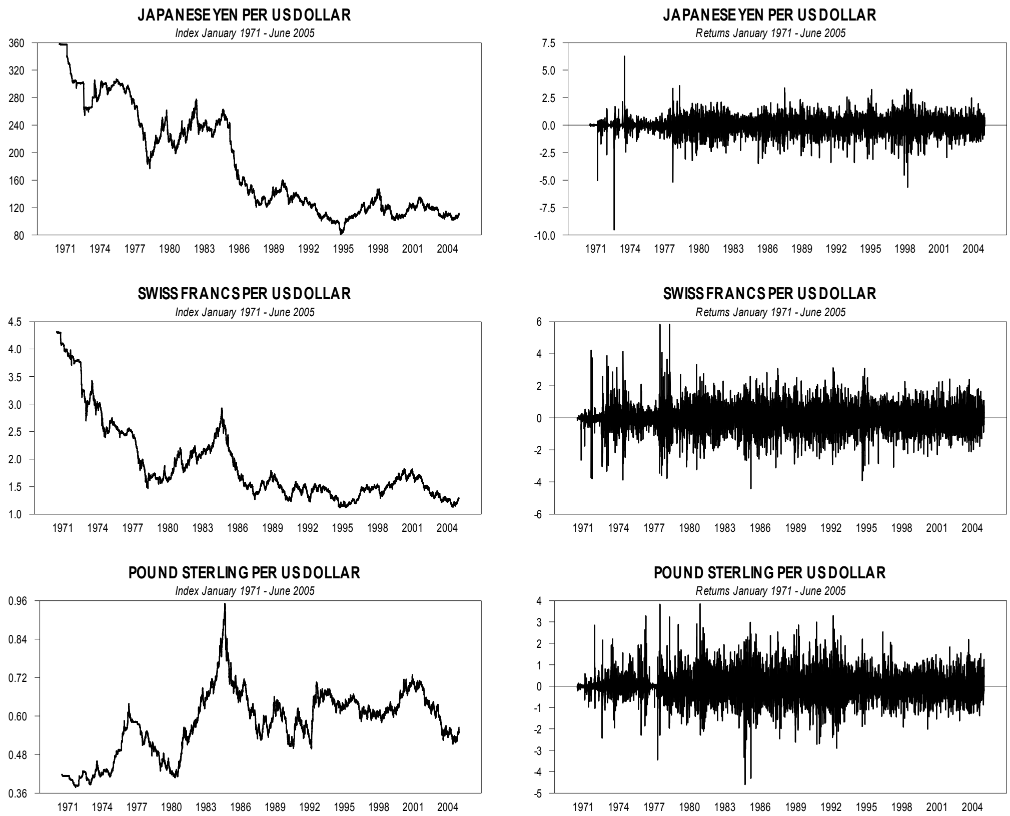
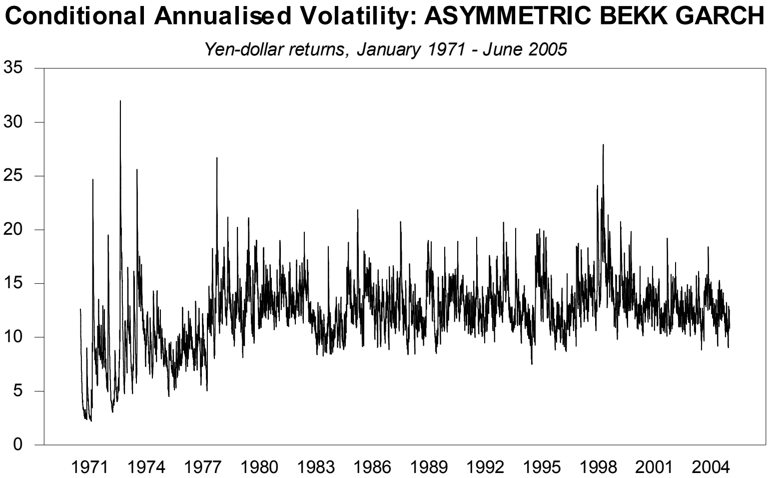
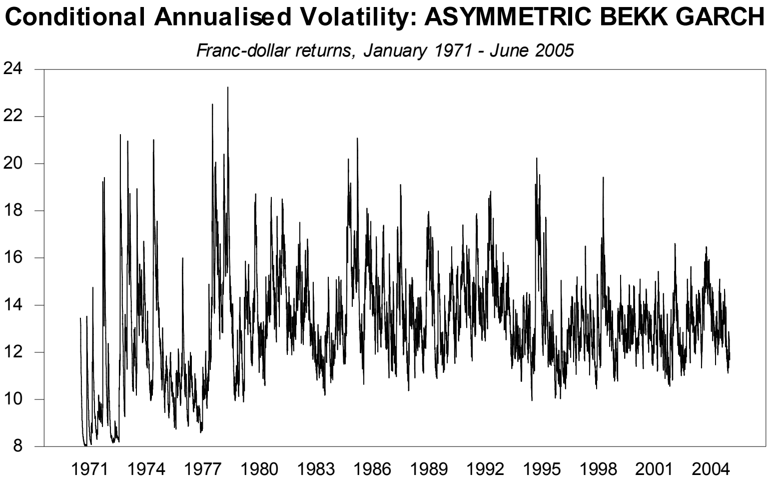


Figure 2: Conditional Variances





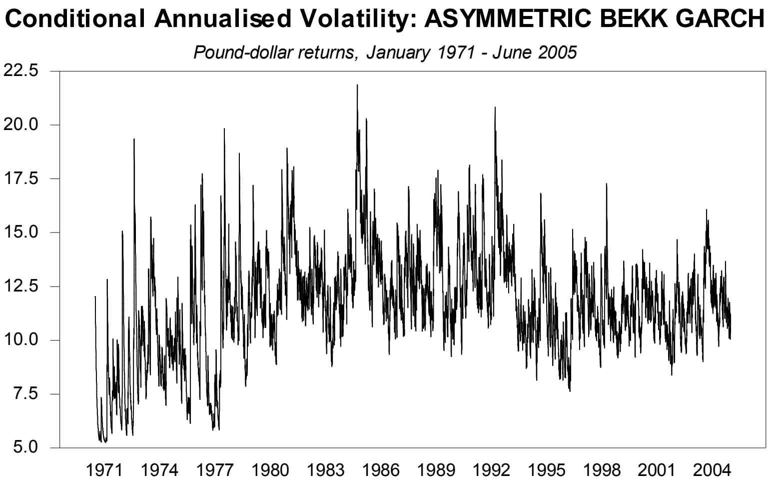
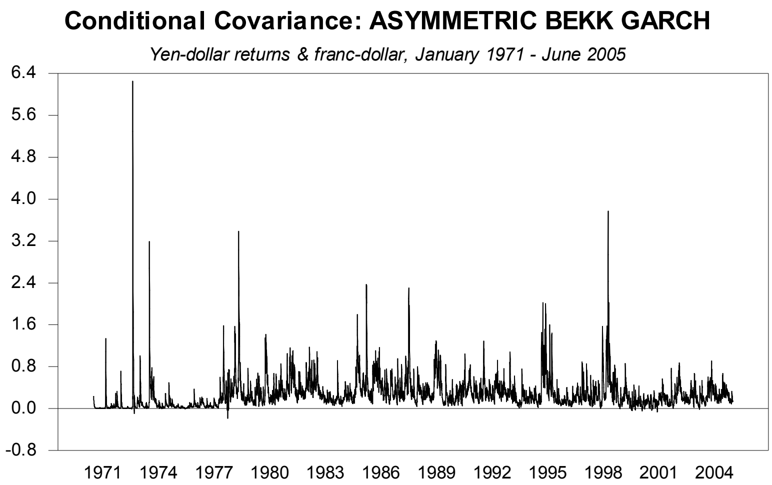
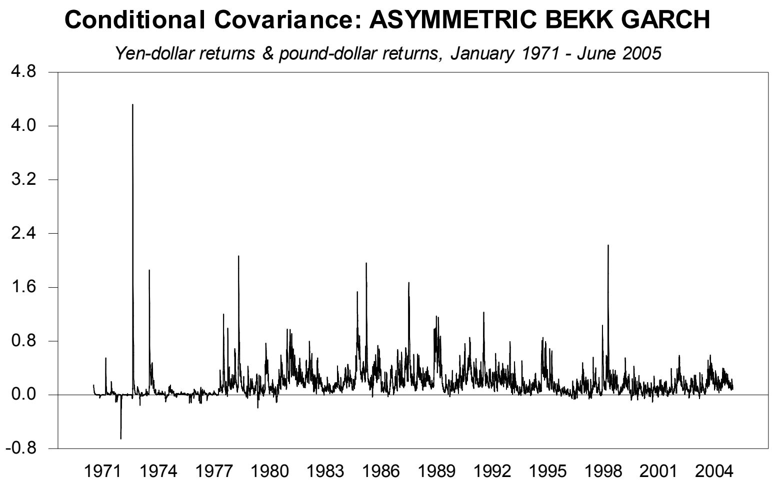


Figure 3: Conditional Covariances





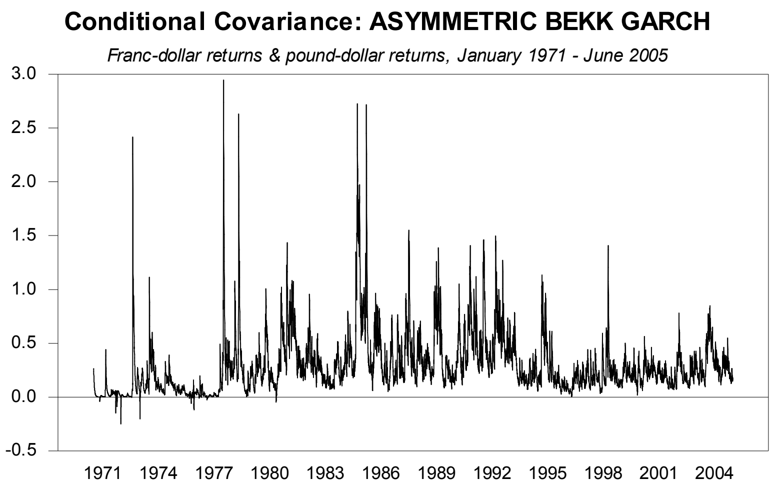
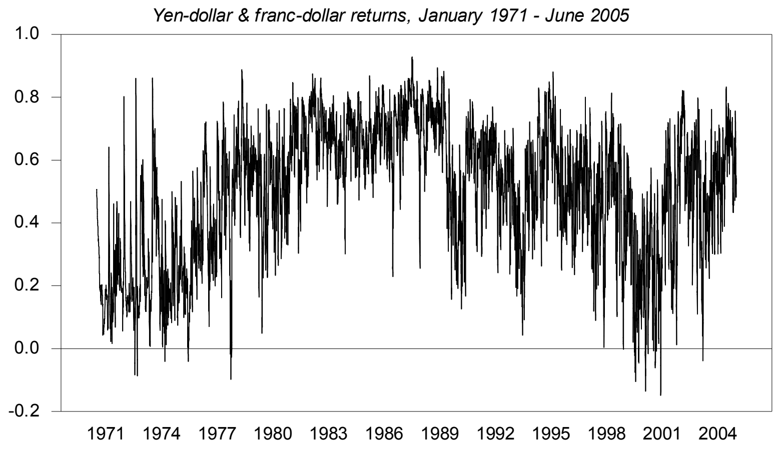
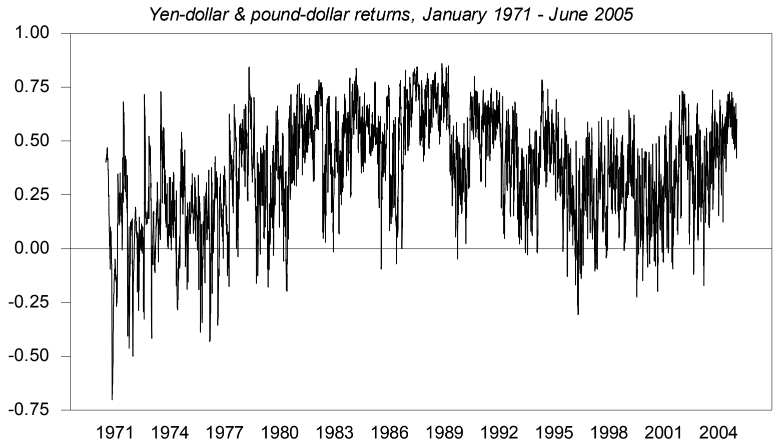


Figure 4: Conditional Correlations

Time Varying Conditional Correlation: ASYMMETRIC BEKK GARCH



Time Varying Conditional Correlation: ASYMMETRIC BEKK GARCH



Time Varying Conditional Correlation: ASYMMETRIC BEKK GARCH