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Exchange Rate Uncertainty and International Portfolio Flows

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Abstract

This paper examines the impact of exchange rate uncertainty on different components of portfolio flows, namely equity and bond flows, as well as the dynamic linkages between exchange rate volatility and the variability of these two types of flows. Specifically, a bivariate GARCH-BEKK-in-mean model is estimated using bilateral data for the US *vis-à-vis* Australia, the UK, Japan, Canada, the euro area, and Sweden over the period 1988:01-2011:12. The results indicate that the effect of exchange rate uncertainty on equity flows is negative in the euro area, the UK and Sweden, and positive in Australia, whilst it is negative in all countries except Canada (where it is positive) in the case of bond flows. Under the assumption of risk aversion, this suggests that exchange rate uncertainty induces a home bias and causes investors to reduce their financing activities to maximise returns and minimise exposure to uncertainty. Furthermore, since exchange rate volatility and the variability of flows are interlinked, exchange rate or credit controls on these flows can be used to pursue economic and financial stability.

Keywords: Exchange rate uncertainty, Equity flows, Bond flows, Causality-in-variance
JEL Classification: F31, F32, G15

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1. Introduction

The macroeconomic effects of exchange rate uncertainty, especially on trade flows, have attracted considerable attention since the collapse of the Bretton Woods system in 1971 and the adoption of floating exchange rates in March 1973, both in the theoretical and empirical literature (see McKenzie, 1999, for a comprehensive review). By contrast, the impact at the micro level on equity and bond flows has yet to be investigated empirically.

In an influential study, Hau and Rey (2006) develop an equilibrium framework in which exchange rate returns, equity returns, and capital flows are jointly determined under incomplete foreign exchange risk trading. Their analysis is motivated by the recent microstructure approach to exchange rate determination which has been shown to improve remarkably the performance of exchange rate models, with currency order flows explaining a substantial proportion of exchange rate changes (see, e.g., Evans and Lyons, 2002; 2005; 2008; Payne, 2003; Rime et al., 2010; Chinn and Moore, 2011; and Duffuor et al., 2012 among others). In addition, they argue that currency order flows and portfolio flows are intimately related within the portfolio rebalancing framework since they both reflect investors' behaviour. However, while their paper provides a theoretical framework for analysing the implications of incomplete foreign exchange risk trading for the correlation structure of exchange rate changes and equity returns as well as net portfolio flows, it does

not include statistical tests for the impact of exchange rate uncertainty on portfolio flows across borders.

The underlying idea is that exchange rate volatility increases transaction costs and reduces potential gains from international diversification by making the acquisition of foreign securities such as bonds and equities more risky, which in turn affects negatively portfolio flows across borders. Indeed, Eun and Resnick (1988) had previously shown that exchange rate uncertainty is non-diversifiable and has an adverse impact on the performance of international portfolios. This finding is also consistent with the evidence presented in the study by Levich et al. (1999), who found, by surveying 298 US institutional investors, that foreign exchange risk hedging constitutes only 8% of total foreign equity investment. However, Eun and Resnick (1988) suggest that hedging through forward exchange contracts and multicurrency diversification are effective ways to reduce exchange rate risk. Glen and Jorion (1993) and Eun and Resnick (1994) further provide evidence that hedging in the forward exchange markets improves the performance of diversified portfolios of equities and bonds.

The present study makes a fourfold contribution to the existing literature. First, it analyses empirically whether exchange rate uncertainty affects international portfolio flows and their variability. It is in fact the first empirical investigation of this kind, based on bilateral monthly data for the US vis-à-vis six developed economies, namely Australia,

Canada, the euro area, Japan, Sweden, and the UK over the period 1988:01-2011:12. Second, unlike Hau and Rey (2006) who assume that the supply of bonds is infinitely elastic, thereby simplifying the dynamics of bond acquisitions in their model, we examine the impact of exchange rate uncertainty on bond and equity flows (as well as their variability) in turn. In this way, we are able to evaluate the impact of uncertainty on the individual components of portfolio flows across borders. According to Hau and Rey (2006), exchange rate uncertainty should affect equity, but not bond flows; we provide some relevant empirical evidence on this issue.

Third, existing empirical studies on the relationship between exchange rate changes and portfolio flows investigate short-run dynamic interactions only with linear dependence techniques (i.e., first moment analysis). For example, Brooks et al. (2004) and Hau and Rey (2006) use simple correlations and regression analysis for the US vis-à-vis the euro area and Japan, and 17 OECD countries respectively; Siourounis (2004), Chaban (2009), and Kodong and Ojah (2012) estimate VAR models for four developed countries (the UK, Japan, Germany, and Switzerland), three oil-exporting countries (Canada, Australia, and New Zealand), and four African countries (Egypt, Morocco, Nigeria, and South Africa) vis-à-vis the US. Their results are characterised by significant deviations from normality and conditional heteroscedasticity, i.e. volatility clustering or the so-called ARCH effects (see Engle, 1982) that are not captured by their setup. By contrast, we model first and second

moments simultaneously to analyse the dynamic interactions between exchange rate changes and portfolio flows, in this way avoiding the potential pitfalls of earlier studies.

Fourth, since volatility is a measure of the information flow (see Ross, 1989), it is of paramount importance to understand how the stochastic information arrivals in the form of simple portfolio investment shifts in bonds and equities are transmitted to the foreign exchange market, and viceversa. Our analysis sheds light on this mechanism and thus provides important information to policy-makers and regulators to formulate appropriate policies based on imposing or relaxing credit controls on these flows depending on the state of the economy, with the aim of achieving economic and financial stability.

The remainder of the paper is organised as follows. Section 2 describes the data and reports some descriptive statistics. Section 3 outlines the econometric model. Section 4 discusses the empirical results, and finally Section 5 concludes.

2. The econometric model

We employ a bivariate VAR-GARCH (1, 1) in the BEKK specification (Engle and Kroner, 1995) allowing for in-mean effects in order to examine the impact of exchange rate uncertainty on equity and bond flows as well as the dynamic linkages in the first and second moments of these variables over the period 1988:01-2011:12. Various lags of exchange rate

volatility affecting the conditional mean of equity and bond flows are included in the specification to avoid the potential pitfalls of models allowing only for contemporaneous interactions. The economic interpretation is that it might take some time for the investors' response to exchange rate volatility to be incorporated into their strategies. Therefore the conditional mean equation is specified as follows:

$$y_t = \mu + \sum_{i=1}^{p} \psi_i y_{t-i} + \sum_{i=1}^{p} \lambda_i h_{t-i} + \varepsilon_t$$

$$\mu = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix}; \psi_i = \begin{bmatrix} \psi^i_{11} & \psi^i_{12} \\ \psi^i_{21} & \psi^i_{22} \end{bmatrix}; \lambda_i = \begin{bmatrix} \lambda^i_{11} & \lambda^i_{12} \\ \lambda^i_{21} & \lambda^i_{22} \end{bmatrix}; \varepsilon_t = \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix} \quad (1)$$

where y_t =$[E_t, EF_t(BF_t)]$, E_t and EF_t (BF_t) indicate respectively exchange rate changes and net equity (bond) flows. h_t =$[h_{11,t}, h_{22,t}]$, $h_{11,t}$ and $h_{22,t}$ represent the conditional variances of exchange rate changes and net flows depending on whether equities or bonds respectively are considered. The parameters $\psi_{11}^{(i)}$, $\psi_{22}^{(i)}$ measure the response of exchange rate changes and net flows to their own lags, whilst $\psi_{21}^{(i)}, \psi_{12}^{(i)}$ represent the mean spillovers from exchange rate changes to net flows, and viceversa. If the parameter λ_{21}^{i} is significantly different from zero, this implies that exchange rate uncertainty affects equity flows and/or bond flows. The innovations vector is assumed to be normally distributed $\varepsilon_t|\Omega_{t-1} \sim (0, H_t)$ with its corresponding variance-covariance matrix given by $|H_t|$; Ω_{t-1} is the information set

available at time *t*-1. Lags are included sequentially in Equ. (1) until serial correlation is removed by employing the Hosking (1981) multivariate *Q*-statistics on the standardised residuals $z_{it} = \varepsilon_{it}/\sqrt{h_{it}}$ for i = 1, 2.

Note that cointegration tests between exchange rates and net flows have not been carried out as the former appear to be I (1) in most cases, whilst both equity and bond flows follow I (0) processes [1] (see Fig. 1). Hence, an error correction term is not included in Equ. (1).

Having specified the conditional mean equation, we then estimate the multivariate GARCH model in its BEKK representation, this being a straightforward generalisation of the univariate GARCH model of Bollerlslev (1986). The BEKK specification has advantages compared to other multivariate GARCH specifications such as the VEC-GARCH model of Bollerslev et al. (1988) because of its quadratic forms ensuring that the conditional covariance matrices in the system are positive definite.[2] Unlike the Dynamic Conditional Correlation model of Engle (2002), which estimates the time-varying correlations directly, the BEKK specification allows for time-varying correlations and also for interactions between the variances in a lead-lag framework. Furthermore, the curse of dimensionality highlighted by Caporin and McAleer (2012) is not a serious issue in the present case with only two variables. The model can be represented as follows:

[1] This is confirmed by a battery of unit root tests; the results are available from the authors on request.

[2] For a survey on multivariate GARCH models, see Bauwens et al. (2006).

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B \tag{2}$$

In matrix form, it can be specified as:

$$\begin{bmatrix} H_{11,t} & H_{12,t} \\ H_{21,t} & H_{22,t} \end{bmatrix} = C'C + A'\begin{bmatrix} u^2_{1,t-1} & u_{1,t-1}u_{2,t-1} \\ u_{2,t-1}u_{1,t-1} & u^2_{2,t-1} \end{bmatrix}A + B'\begin{bmatrix} H_{11,t-1} & H_{12,t-1} \\ H_{21,t-1} & H_{22,t-1} \end{bmatrix}B \tag{3}$$

$$C = \begin{bmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{bmatrix}, A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}, B = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$

where *C* is constrained to be a lower triangular matrix and *A* and *B* are respectively ARCH and GARCH parameter matrices. Equ. (3) shows that in the BEKK model each conditional variance and covariance in H_t is modelled as a function of lagged conditional variances and covariances, lagged squared innovations and the cross-product of the innovations. Volatility is transmitted between exchange rate changes and net equity/bond flows through two channels represented by the off-diagonal parameters in the ARCH and GARCH matrices: a symmetric shock $u_{i,t-1}$ and the conditional variance $H_{ii,t-1}$. Volatility transmission from exchange rate changes to net equity/bond flows can be analysed by testing the null hypothesis $a_{12} = b_{12} = 0$, and $a_{21} = b_{21} = 0$ in the opposite direction. Such causality-in-variance tests within the multivariate GARCH-BEKK models have superior power to the cross correlation function

(CCF) two-step approach of Cheung and Ng (1996) (see Hafner and Hewartz, 2008). Causality-in-variance is tested using the following likelihood ratio test statistic:

$$LR = -2(L_r - L_{ur}) \sim x^2_{df} \quad (4)$$

where L_r and L_{ur} indicate the restricted and unrestricted log-likelihood test statistic; *LR* follows the chi-squared distribution with degrees of freedom equal to the number of the restricted coefficients (*df*).

Given that, as stated earlier, the innovations are assumed to be normally distributed, the log likelihood function for such a model is given by:

$$L(\theta) = \frac{-Tn}{2}\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{t}(\ln|H_t| + \varepsilon'_t H^{-1}{}_t \varepsilon_t) \quad (5)$$

where *n* is the number of equations, two in our case; *T* is the number of observations, which is 287; and θ is a vector of unknown parameters to be computed. More specifically, we use the Quasi-Maximum Likelihood (QML) method of Bollerslev and Woolbridge (1992) to calculate the standard errors that are robust to deviations from normality.[3] As a final check of the

[3] We use the SIMPLEX free-derivative method, which is useful to improve the initial values, and then the BFGS standard algorithm to obtain the standard errors (see Engle and Kroner, 1995; Kearney and Patton, 2000 among others). This procedure was implemented with a convergence criterion of 0.00001.

adequacy of the estimated model we employ the Hosking (1981) multivariate *Q*-statistic for the standardised squared residuals to evaluate whether or not the ARCH and GARCH dynamics have been appropriately captured in the conditional variance equation, Equ. (3).

3. Data description

We examine the impact of exchange rate uncertainty on different components of portfolio flows, namely equity and bond flows, as well as the dynamic linkages between these flows and exchange rate changes for the US *vis-à-vis* the UK, Japan, Canada, Australia, Sweden, and the euro area. Throughout, the US is considered the domestic or home economy. Since the data on portfolio investment flows, obtained from the US *Treasury International Capital (TIC) System*,[4] are sampled at a monthly frequency, we employ monthly data from 1988:01 to 2011:12 for all series. The reason for selecting this start date is that portfolio flows for the period preceding 1988 are known to be insignificant (see Brooks et al., 2004). Net equity (bond) flows are calculated as equity (bond) *inflows* minus *outflows*. While *inflows* are measured as net purchases and sales of domestic (US) assets (equities and bonds) by foreign residents, *outflows* are measured as net purchases and sales of foreign assets (equities and bonds) by domestic residents (US). With regard to the euro area, we aggregate the data for the

[4] They are retrieved from the US Treasury Department website http://www.treasury.gov/resource-center/data-chart-center/tic/Pages/country-longterm.aspx

individual EMU countries (Austria, Belgium-Luxemburg, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal, Spain) to extract cross-border bond and equity flows between the US and this region.

Positive numbers imply net equity and bond inflows (in millions of US dollars) towards the US or outflows from the counterpart countries. Following Brennan and Cao (1997), Hau and Rey (2006), and Chaban (2009) among others, we normalise these flows using the average of their absolute values over the previous 12 months, since without scaling model convergence is difficult to achieve. The exchange rates are end of period data, defined as US dollars per unit of foreign currency; the source is the IMF's *International Financial Statistics (IFS).* Exchange rate changes are calculated as $E_t = 100 \times P_{E,t}/P_{E,t-1}$ where $P_{E,t}$ represents the log of the exchange rate at time *t*. For the period preceding the inception of the euro, i.e. before 1999, we use US dollar per ECU as the euro area's exchange rate.

Descriptive statistics are displayed in Table 1. The mean of monthly exchange rate changes is positive (US dollar depreciation) for Japan and Canada, and negative (US dollar appreciation) for the rest of the countries. On the other hand, the monthly mean of net equity flows is positive for Sweden and Canada and negative for the remaining countries, indicating equity inflows from Sweden and Canada towards the US and outflows from the US towards the other countries. The monthly mean of net bond flows is negative for Australia and positive

for the other countries. This indicates the existence of bond inflows from all countries except Australia (for which there is evidence of bond outflows) vis-à-vis the US.

Exchange rate changes are found to exhibit higher volatility than the two flows. Furthermore, equity flows appear to be characterised by higher volatility than bond flows (although their volume is very small). As for the third and fourth moments, exchange rate changes, net equity flows, and net bond flows all exhibit skewness and excess kurtosis in most cases. The Jarque-Bera (JB) test statistics imply a rejection at the 1% level of the null hypothesis that exchange rate changes and the two flows are normally distributed in all countries in question.

[Insert Table 1 about here]

Fig. 1 shows monthly exchange rate changes, net equity flows and net bond flows for all countries over the period under investigation. Volatility clustering is clearly present in all cases, suggesting that an ARCH model might be required to capture it. The series also appear to be covariance stationary.

[Insert Fig. 1 about here]

4. Empirical results

The microstructure approach is particularly suited to analysing the relationship between bond and equity flows and exchange rate changes. The objective of our analysis is to establish whether exchange rate uncertainty affects equity and bond flows across borders, and also whether there is a volatility transmission (hence information flows) between these flows and exchange rate changes and, if so, in what direction causality runs.

The QML estimates of the bivariate GARCH **(**1, 1)–BEKK parameters as well as the associated multivariate *Q*-statistics (Hosking, 1981) are displayed in Tables 2–7 for Australia, Canada, the euro area, Japan, Sweden, and the UK, respectively. Panel A and B in each Table concern the bivariate regression of exchange rate changes against equity and bond flows respectively. The Hosking multivariate *Q*-statistics of order (6) and (12) for the standardised residuals in the exchange rate changes-equity flows equation indicate the existence of no serial correlation at the 5% level, when the conditional mean equations are specified with p=1 for Japan, p=2 for Sweden and p=3 for the other countries (the insignificant parameters in the mean equations have been dropped). With regard to the exchange rate changes-bond flows relationship, whilst no dynamic terms appear to be necessary for Sweden, setting p=1 for the UK, p=2 for the euro area, p=3 for Australia and Canada and p=5 for Japan is required to capture adequately the dynamic structure in these cases.

[Insert Tables 2-7 about here]

As can be seen from the Tables, the dynamic interactions between exchange rate changes and net equity and bond flows, captured by $\psi_{12}^{(i)}$ and $\psi_{21}^{(i)}$, suggest that there exist limited dynamic linkages between the first moments compared to the second ones. The results in the mean equation indicate the existence of mean spillovers between exchange rate changes and net bond flows in Japan, from bond flows to exchange rate changes in Canada and the UK, and from equity flows to exchange rate changes in the euro area.

With regard to the impact of exchange rate uncertainty on equity flows, the results suggest that exchange rate volatility affects equity flows negatively in the euro area, Sweden, and the UK, and positively in Australia, and has no effect in Canada and Japan. Its impact on bond flows, on the other hand, appears to be negative in all countries except Canada for which it is positive.

The observed negative impact on equity as well as bond flows has important implications. First, it indicates that risk averse market participants respond to exchange rate uncertainty by reducing their financing activities, hence favouring domestic rather than foreign securities in their portfolios to reduce their exposure to exchange rate volatility.

Second, in contrast to Hau and Rey (2006) who assume that bonds are usually hedged instruments not affected by exchange rate uncertainty, it appears that uncertainty in fact affects bond as well as equity flows, and the former more widely, since a negative impact is found in five of the six countries considered. This is consistent with the results of Fidora et al.

(2007), who found in a wide set of industrialised and emerging economies that exchange rate volatility is an important factor for bilateral portfolio home bias, this being higher for bonds than for equities. Their rationalisation of the higher home bias for bonds compared to equities is that it is consistent with Markowitz-type international CAPM specifications in which less volatile financial assets should show larger home bias.

The estimates of the conditional variance equations indicate that exchange rate changes (net equity/bond flows) exhibit conditional heteroscedasticity: the diagonal elements of the ARCH matrices are significant at the 10% level in all cases except for equity flows in Australia and bond flows in Australia, Sweden, and the UK. Furthermore, the conditional variances exhibit persistence in all cases except for equity flows in Canada. While the persistence of the conditional variance of exchange rate changes ranges from 0.54 (Japan) to 0.98 (euro area), the persistence of the corresponding flows ranges from 0.38 (Sweden) to 0.91 (euro area) for net equity flows and from 0.43 (Japan) to 0.98 (Canada) for net bond flows.

The ARCH, α_{11}, and GARCH, β_{11}, estimates for exchange rate changes in the bivariate GARCH–BEKK models are rather similar, regardless of whether the relationship with bond or equity flows is considered (see Panels A and B respectively in all Tables). More specifically, the change in α_{11} is less than 10% and this also applies to β_{11}, except for Japan where the change is around 26%. Furthermore, the off-diagonal elements of the ARCH and

GARCH matrices indicate that shocks to exchange rate changes (net equity flows) affect the conditional variance of net equity flows (exchange rate changes) at the 10% level in the euro area and Japan. The results also show that shocks to exchange rate changes (net bond flows) affect the conditional variance of net bond flows (exchange rate changes) at the 10% level in all cases except Japan.

More specifically, the causality-in-variance (i.e., the information flow) tests based on likelihood ratio test statistics provide evidence of strong causality-in-variance from equity flows to exchange rate changes in the case of the euro area and bidirectional causality-in-variance in the case of Japan. There is also causality-in-variance from bond flows to exchange rate changes in Australia, the euro area, and Sweden, as well as bidirectional causality in Canada and the UK. A possible explanation for the existence of stronger dynamic linkages between exchange rate changes and bond flows rather than equity flows is that foreign exchange dealers usually follow bond yields in their trading behaviour, with such yields, in turn, driving cross-border bond acquisitions, which results in volatile exchange rates. Spillovers from the exchange rates may also be due to the fact that investors adjust their portfolios on the basis of their volatility. Also, the limited linkage between exchange rate changes and bond flows in Japan can be explained by the fact that a high percentage of Japanese debt is financed internally, primarily by Japanese pension funds, hence bilateral

bond flows between the US and Japan have no impact on exchange rate volatility, and viceversa.

Finally, the Hosking multivariate *Q*-statistics of order (6) and (12) for the squared standardised residuals suggest that the multivariate GARCH (1, 1) structure is sufficient to capture the volatility in the series.

5. Conclusions

In this paper, we have analysed the impact of exchange rate uncertainty on bond and equity flows, as well as the dynamic linkages between exchange rate volatility and the variability of these flows, using data for the US vis-à-vis six advanced economies, namely Australia, the UK, Canada, Japan, Sweden, and the euro area over the period 1988:01-2011:12. Estimating bivariate GARCH–BEKK–in–mean models, we find evidence that exchange rate volatility impacts on equity flows negatively in the euro area, Sweden, and the UK and positively in Australia. Furthermore, in contrast to Hau and Rey (2006), it also affects bond flows negatively in all countries except Canada where the effect is positive. The general conclusion that can be drawn from these results is that exchange rate volatility induces risk averse investors to reduce their financing activities and to favour domestic to foreign assets in their portfolios in order to minimise their exposure to volatility.

The causality-in-variance analysis suggests the existence of strong spillovers from equity flows to exchange rate changes in the euro area and bidirectional causality-in-variance in Japan. As for the linkages between exchange rate changes and bond flows, causality-in-variance from bond flows to exchange rate changes is found for Australia, the euro area, and Sweden, and bidirectional causality for Canada and the UK. These findings have important policy implications, since they suggest that policy-makers and economic and financial regulators could use exchange rate or credit controls on equity as well as bond flows as instruments to achieve economic and financial stability.

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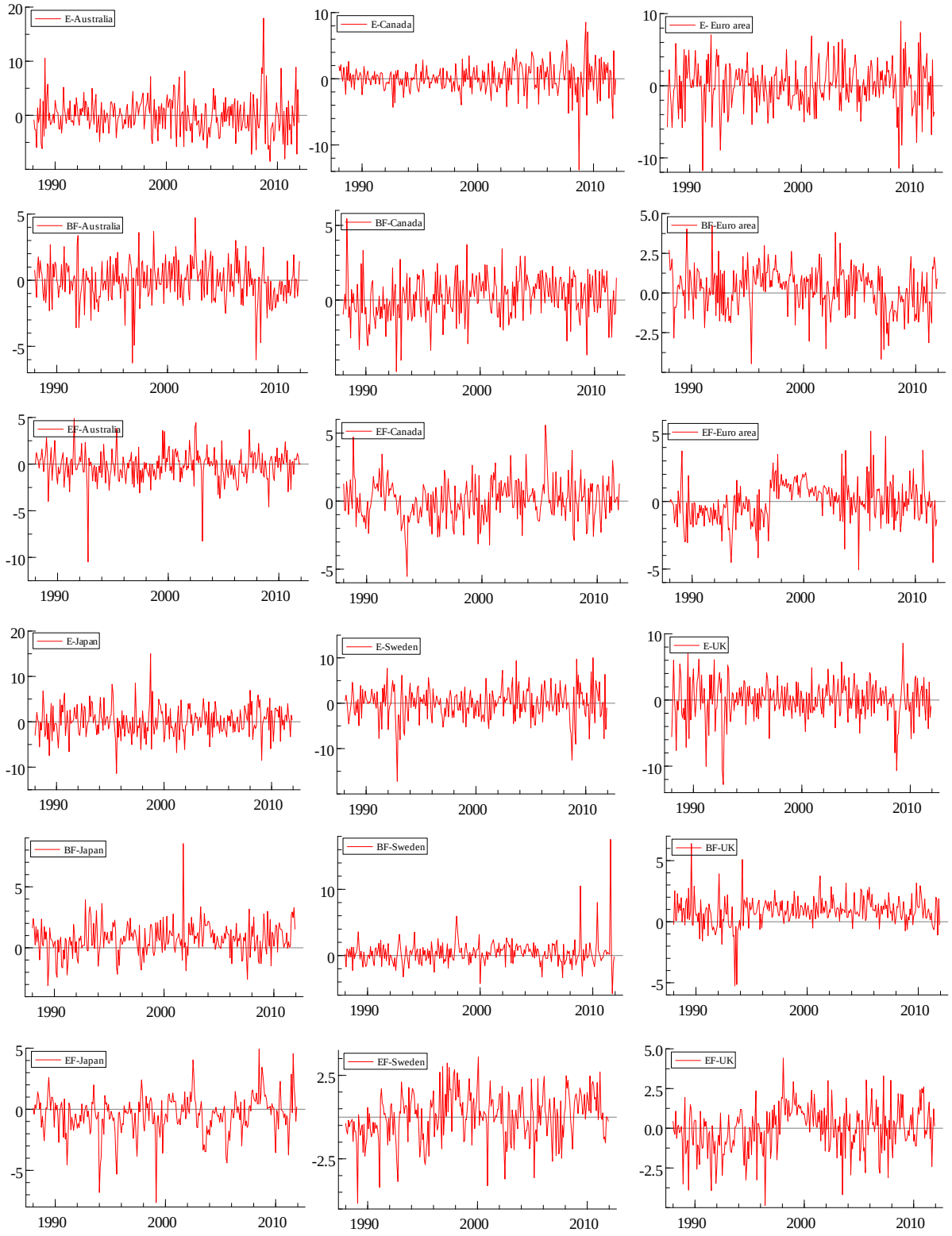

Fig. 1. Time series of exchange rate changes (*E*), net bond flows (*BF*), and net equity flows (*EF*) of the six advanced economies over the period 1988:01–2011:12.

Table 1

Summary of descriptive statistics for the normalized net portfolio flows and exchange rate changes.

Statistics	Variable	Australia	Canada	Euro area	Japan	Sweden	UK
Mean	E_t	-0.122	0.083	-0.002	0.160	-0.047	-0.066
	EF_t	-0.200	0.068	-0.051	-0.432	0.020	-0.017
	BF_t	-0.106	0.191	0.222	0.718	0.260	0.848
St. Dev	E_t	3.270	2.148	3.080	3.088	3.439	2.855
	EF_t	1.599	1.443	1.487	1.552	1.729	1.414
	BF_t	1.467	1.394	1.358	1.251	1.638	1.136
Skewness	E_t	0.790	-0.692	-0.375	0.221	-0.554	-0.738
	EF_t	-1.129	0.144	0.028	-0.631	-1.333	-0.342
	BF_t	-0.446	-0.202	-0.365	0.634	0.379	-0.385
Ex. kurtosis	E_t	6.226	9.417	4.119	4.958	5.410	5.634
	EF_t	10.619	4.301	4.157	6.103	8.363	3.607
	BF_t	4.988	3.830	3.665	7.905	7.914	9.786
JB	E_t	154.31^{***}	515.38^{***}	21.713^{***}	48.195^{***}	84.171^{***}	109.07^{***}
	EF_t	755.30^{***}	21.262^{***}	16.065^{***}	134.21^{***}	429.01^{***}	10.021^{***}
	BF_t	56.834^{***}	10.207^{***}	11.691^{***}	306.95^{***}	295.67^{***}	557.86^{***}

Notes: E_t, EF_t, and BF_t indicate exchange rate changes, net equity flows, and net bond flows, respectively; JB is the Jarque-Bera test for normality.

*** indicate significance at the 1 % level.

Table 2

The estimated bivariate GARCH–BEKK–in– mean model for Australia.

Panel A: Exchange rates (E_t) and equity flows (EF_t)			Panel B: Exchange rates (E_t) and bond flows (BF_t)		
	E_t (i=1)	EF_t (i=2)		E_t (i=1)	BF_t (i=2)
Conditional Mean Equation					
μ_i	-0.015 (0.159)	-0.348^{***} (0.120)	μ_i	-0.128 (0.157)	0.158 (0.129)
$\psi_{2i,t-2}$	–	0.157^{***} (0.079)	$\psi_{2i,t-3}$	–	0.129^{***} (0.049)
$\psi_{1i,t-3}$	0.110^{*} (0.062)	–	$\eta_{2i,t}$	-0.026^{**} (0.010)	–
$\eta_{2i,t-5}$	0.014^{*} (0.007)	–			
Conditional Variance Equation					
c_{1i}	0.496^{***} (0.496)	0	c_{1i}	-0.103 (0.281)	0
c_{2i}	-0.042 (1.760)	1.352^{**} (0.545)	c_{2i}	0.753^{***} (0.129)	-0.00008 (1.148)
α_{1i}	0.363^{***} (0.087)	0.027 (0.058)	α_{1i}	0.254^{***} (0.046)	-0.011 (0.030)
α_{2i}	-0.133 (0.241)	-0.205 (0.311)	α_{2i}	0.380^{***} (0.076)	0.076 (0.152)
b_{1i}	0.920^{***} (0.037)	0.014 (0.039)	b_{1i}	0.949^{***} (0.010)	0.001 (0.004)
b_{2i}	0.062 (0.785)	0.472^{*} (0.256)	b_{2i}	0.033 (0.071)	0.849^{***} (0.065)
Loglik	-1254.543		*Loglik*	-1225.385	
$Q(6)$	27.654[0.274]	$Q^2(6)$ 9.823[0.981]	$Q(6)$	12.073 [0.979]	$Q^2(6)$ 26.041 [0.204]
$Q(12)$	49.470[0.414]	$Q^2(12)$ 30.46[0.952]	$Q(12)$	31.67 [0.966]	$Q^2(12)$ 48.899 [0.319]

Tests of No Volatility Transmission:		Tests of No Volatility Transmission:	
(i) Bidirectional between E_t and EF_t		(i) Bidirectional between E_t and BF_t	
$H_0 : \alpha_{12} = \alpha_{21} = b_{12} = b_{21} = 0$	LR=1.748[0.781]	$H_0 : \alpha_{12} = \alpha_{21} = b_{12} = b_{21} = 0$	LR=11.66 [0.020]
(ii) From E_t to EF_t		(ii) From E_t to BF_t	
$H_0 : \alpha_{12} = b_{12} = 0$	LR=0.125[0.939]	$H_0 : \alpha_{12} = b_{12} = 0$	LR=0.135 [0.934]
(iii) From EF_t to E_t		(iii) From BF_t to E_t	
$H_0 : \alpha_{21} = b_{21} = 0$	LR=1.639[0.440]	$H_0 : \alpha_{21} = b_{21} = 0$	LR=10.37 [0.005]

Note: E_t, EF_t, and BF_t indicate exchange rate changes, net equity flows, and net bond flows, respectively; while LR indicates likelihood ratio test statistics. Heteroscedasticity-consistent standard errors are in parentheses (.), whereas p-values are reported in [.]. Q (p) and Q^2 (p) are multivariate Hosking (1981) tests for p^{th} order serial correlation on the standardized residuals z_{it} and their squares z_{it}^2, respectively where i = 1 (for exchange rate changes (E_t)), 2 (for net equity flows (EF_t) and net bond flows (BF_t)). The covariance stationarity condition is satisfied by all the estimated models, all the eigenvalues of ($A_{11}\otimes A_{11} + B_{11}\otimes B_{11}$) being less than one in modulus.

*** indicates statistical significance at the 1% level.

** indicates statistical significance at the 5% level.

* indicates statistical significance at the 10% level.

Table 3

The estimated bivariate GARCH–BEKK–in–mean model for Canada.

Panel A: Exchange rates (E_t) and equity flows (EF_t)			Panel B: Exchange rates (E_t) and bond flows (BF_t)		
	E_t (i=1)	EF_t (i=2)		E_t (i=1)	BF_t (i=2)
Conditional Mean Equation					
μ_i	-0.034 (0.097)	0.065 (0.081)	μ_i	-0.035 (0.099)	0.160^{*} (0.084)
$\psi_{2i,t-1}$	–	0.249^{***} (0.061)	$\psi_{1i,t-2}$	–	0.136^{*} (0.067)
$\psi_{2i,t-3}$	–	0.143^{***} (0.053)	$\psi_{2i,t-3}$	–	0.121^{*} (0.070)
			$\eta_{2i,t}$	0.026^{*} (0.013)	–
Conditional Variance Equation					
c_{1i}	0.060 (0.164)	0	c_{1i}	0.230^{**} (0.108)	0
c_{2i}	1.270^{***} (0.224)	0.00102 (3.260)	c_{2i}	0.0005 (0.063)	-0.0000007 (0.012)
α_{1i}	0.328^{***} (0.050)	-0.017 (0.061)	α_{1i}	0.314^{**} (0.047)	-0.070^{**} (0.031)
α_{2i}	-0.001 (0.097)	0.260^{**} (0.131)	α_{2i}	0.0002 (0.038)	-0.109^{***} (0.036)
b_{1i}	0.921^{***} (0.034)	-0.097 (0.103)	b_{1i}	0.947^{***} (0.018)	0.017^{**} (0.008)
b_{2i}	-0.274^{*} (0.158)	-0.242 (0.603)	b_{2i}	0.004 (0.013)	0.989^{***} (0.006)
Loglik	-1079.477		*Loglik*	-1075.085	
$Q(6)$	16.201 [0.880]	$Q^2(6)$ 13.294 [0.897]	$Q(6)$	13.329 [0.960]	$Q^2(6)$ 8.539 [0.992]
$Q(12)$	29.301 [0.984]	$Q^2(12)$ 37.210 [0.788]	$Q(12)$	31.505 [0.968]	$Q^2(12)$ 30.70 [30.70]

Tests of No Volatility Transmission:

(i) Bidirectional between E_t and EF_t

$H_0 : \alpha_{12} = \alpha_{21} = b_{12} = b_{21} = 0$ *LR*=2.011[0.733]

(ii) From E_t to EF_t

$H_0 : \alpha_{12} = b_{12} = 0$ *LR*=1.238[0.538]

(iii) From EF_t to E_t

$H_0 : \alpha_{21} = b_{21} = 0$ *LR*=0.798[0.670]

Tests of No Volatility Transmission:

(i) Bidirectional between E_t and BF_t

$H_0 : \alpha_{12} = \alpha_{21} = b_{12} = b_{21} = 0$ *LR*=8.697 [0.069]

(ii) From E_t to BF_t

$H_0 : \alpha_{12} = b_{12} = 0$ *LR*=8.116 [0.017]

(iii) From BF_t to E_t

$H_0 : \alpha_{21} = b_{21} = 0$ *LR*=7.770 [0.020]

Note: See notes to Table 2.

Table 4

The estimated bivariate GARCH–BEKK–in–mean model for the euro area.

Panel A: Exchange rates (E_t) and equity flows (EF_t)			Panel B: Exchange rates (E_t) and bond flows (BF_t)		
	E_t (i=1)	EF_t (i=2)		E_t (i=1)	BF_t (i=2)
Conditional Mean Equation					
μ_i	-0.065 (0.178)	1.818^{**} (0.916)	μ_i	0.023 (0.194)	0.627^{***} (0.274)
$\psi_{1i,t-1}$	–	0.229^{**} (0.101)	$\psi_{2i,t-1}$	–	0.142^{**} (0.058)
$\psi_{2i,t-2}$	–	0.314^{***} (0.058)	$\psi_{2i,t-2}$	–	0.171^{***} (0.059)
$\psi_{2i,t-3}$	–	0.129^{**} (0.057)	$\eta_{2i,t-2}$	-0.049^{*} (0.027)	–
$\eta_{2i,t}$	-0.202^{*} (0.105)	–			
Conditional Variance Equation					
c_{1i}	0.480^{***} (0.113)	0	c_{1i}	0.294 (0.252)	0
c_{2i}	-0.819^{***} (0.069)	-0.0001 (0.181)	c_{2i}	0.402^{***} (0.096)	-0.000005 (0.056)
α_{1i}	0.115^{***} (0.030)	0.021 (0.027)	α_{1i}	0.174^{***} (0.066)	0.010 (0.027)
α_{2i}	0.001 (0.074)	0.382^{***} (0.073)	α_{2i}	0.313^{***} (0.120)	-0.159^{***} (0.067)
b_{1i}	0.980^{***} (0.007)	0.003 (0.007)	b_{1i}	0.968^{***} (0.020)	0.018^{***} (0.008)
b_{2i}	0.038 (0.027)	0.910^{***} (0.030)	b_{2i}	-0.134^{***} (0.049)	0.936^{***} (0.021)
Loglik	-1185.161		*Loglik*	-1193.434	
$Q(6)$	20.615 [0.661]	$Q^2(6)$ 24.614 [0.264]	$Q(6)$	18.292 [0.788]	$Q^2(6)$ 11.580 [0.950]
$Q(12)$	43.803 [0.645]	$Q^2(12)$ 40.661 [0.656]	$Q(12)$	40.470 [0.771]	$Q^2(12)$ 40.514 [0.662]

Tests of No Volatility Transmission:		Tests of No Volatility Transmission:	
(i) Bidirectional between E_t and EF_t		(i) Bidirectional between E_t and BF_t	
$H_0 : \alpha_{12} = \alpha_{21} = b_{12} = b_{21} = 0$	*LR*=9.352[0.052]	$H_0 : \alpha_{12} = \alpha_{21} = b_{12} = b_{21} = 0$	*LR*=12.87 [0.011]
(ii) From E_t to EF_t		(ii) From E_t to BF_t	
$H_0 : \alpha_{12} = b_{12} = 0$	*LR*=1.823[0.401]	$H_0 : \alpha_{12} = b_{12} = 0$	*LR*=3.086 [0.213]
(iii) From EF_t to E_t		(iii) From BF_t to E_t	
$H_0 : \alpha_{21} = b_{21} = 0$	*LR*=7.860[0.019]	$H_0 : \alpha_{21} = b_{21} = 0$	*LR*=12.88 [0.001]

Note: See notes to Table 2.

Table 5

The estimated bivariate GARCH–BEKK–in–mean model for Japan.

Panel A: Exchange rates (E_t) and equity flows (EF_t)			Panel B: Exchange rates (E_t) and bond flows (BF_t)		
	E_t (i=1)	EF_t (i=2)		E_t (i=1)	BF_t (i=2)
Conditional Mean Equation					
μ_i	0.112 (0.190)	−0.199** (0.082)	μ_i	0.286 (0.211)	1.472*** (0.426)
$\psi_{1i,t-1}$	0.100* 0.062)	–	$\psi_{1i,t-1}$	–	−0.390*** (0.129)
$\psi_{2i,t-1}$	–	0.530*** (0.046)	$\psi_{2i,t-1}$	0.077*** (0.026)	0.126* (0.073)
			$\psi_{2i,t-2}$	0.065*** (0.020)	−0.084* (0.046)
			$\psi_{1i,t-3}$	0.104** (0.048)	0.037* (0.021)
			$\psi_{2i,t-3}$	0.037* (0.021)	0.101** (0.049)
			$\psi_{1i,t-4}$	−0.098* (0.059)	–
			$\psi_{1i,t-5}$	−0.125** (0.055)	–
			$\eta_{2i,t}$	−0.091* (0.050)	–
Conditional Variance Equation					
c_{1i}	2.192*** (0.300)	0	c_{1i}	1.600*** (0.214)	0
c_{2i}	0.012 (0.266)	−0.000002 (0.156)	c_{2i}	−0.243 (0.196)	0.743*** (0.089)
α_{1i}	0.356*** (0.098)	0.031 (0.032)	α_{1i}	0.265*** (0.073)	−0.047 (0.032)
α_{2i}	0.357 (0.315)	0.327** (0.133)	α_{2i}	−0.259 (0.343)	0.528** (0.229)
b_{1i}	0.542*** (0.132)	−0.231*** (0.031)	b_{1i}	0.799*** (0.030)	0.124*** (0.038)
b_{2i}	0.624* (0.349)	0.753*** (0.081)	b_{2i}	−0.241 (0.265)	0.439* (0.284)
Loglik	-1195.794		*Loglik*	-1157.405	
$Q(6)$	31.611 [0.136]	$Q^2(6)$ 15.878 [0.776]	$Q(6)$	23.606 [0.484]	$Q^2(6)$ 12.521 [0.924]
$Q(12)$	64.352 [0.057]	$Q^2(12)$ 28.645 [0.972]	$Q(12)$	57.582 [0.161]	$Q^2(12)$ 28.743 [0.971]
Tests of No Volatility Transmission:			Tests of No Volatility Transmission:		
(i) Bidirectional between E_t and EF_t			(i) Bidirectional between E_t and BF_t		
$H_0 : \alpha_{12} = \alpha_{21} = b_{12} = b_{21} = 0$		*LR*=16.95 [0.001]	$H_0 : \alpha_{12} = \alpha_{21} = b_{12} = b_{21} = 0$		*LR*=5.822 [0.212]
(ii) From E_t to EF_t			(ii) From E_t to BF_t		
$H_0 : \alpha_{12} = b_{12} = 0$		*LR*=10.55 [0.005]	$H_0 : \alpha_{12} = b_{12} = 0$		*LR*=1.457 [0.482]
(iii) From EF_t to E_t			(iii) From BF_t to E_t		
$H_0 : \alpha_{21} = b_{21} = 0$		*LR*=9.661 [0.007]	$H_0 : \alpha_{21} = b_{21} = 0$		*LR*=4.142 [0.126]

Note: See notes to Table 2.

Table 6

The estimated bivariate GARCH–BEKK–in–mean model for Sweden.

Panel A: Exchange rates (E_t) and equity flows (EF_t)			Panel B: Exchange rates (E_t) and bond flows (BF_t)		
	E_t (i=1)	EF_t (i=2)		E_t (i=1)	BF_t (i=2)
Conditional Mean Equation					
μ_i	0.118 (0.179)	0.045 (0.196)	μ_i	0.066 (0.165)	0.597*** (0.130)
$\psi_{2i,t-1}$	–	0.275*** (0.059)	$\eta_{2i,t}$	−0.028*** (0.024)	–
$\psi_{2i,t-2}$	–	0.137** (0.069)			
$\eta_{2i,t-5}$	−0.013* (0.008)	–			
Conditional Variance Equation					
c_{1i}	1.128 (0.810)	0	c_{1i}	1.174*** (0.308)	0
c_{2i}	−0.567 (0.757)	1.183*** (0.421)	c_{2i}	0.881*** (0.172)	0.000001 (.382)
α_{1i}	0.502*** (0.094)	0.023 (0.047)	α_{1i}	0.422*** (0.093)	0.017 (0.041)
α_{2i}	−0.427* (0.255)	0.506** (0.251)	α_{2i}	−0.433*** (0.097)	0.116 (0.106)
b_{1i}	0.740*** (0.079)	0.013 (0.030)	b_{1i}	0.792*** (0.083)	0.002 (0.023)
b_{2i}	0.680* (0.382)	0.382** (0.185)	b_{2i}	−0.445*** (0.103)	0.828*** (0.061)
Loglik	-1274.357		*Loglik*	-1277.110	
$Q(6)$	17.970 [0.804]	$Q^2(6)$ 10.660 [0.968]	$Q(6)$	24.507 [0.432]	$Q^2(6)$ 16.166 [0.760]
$Q(12)$	34.809 [0.922]	$Q^2(12)$ 30.903 [0.945]	$Q(12)$	39.705 [0.797]	$Q^2(12)$ 37.887 [0.764]

Tests of No Volatility Transmission:		Tests of No Volatility Transmission:	
(i) Bidirectional between E_t and EF_t		(i) Bidirectional between E_t and BF_t	
$H_0 : \alpha_{12} = \alpha_{21} = b_{12} = b_{21} = 0$	*LR*=5.611 [0.230]	$H_0 : \alpha_{12} = \alpha_{21} = b_{12} = b_{21} = 0$	*LR*=13.447 [0.009]
(ii) From E_t to EF_t		(ii) From E_t to BF_t	
$H_0 : \alpha_{12} = b_{12} = 0$	*LR*=0.622 [0.732]	$H_0 : \alpha_{12} = b_{12} = 0$	*LR*=0.3690 [0.831]
(iii) From EF_t to E_t		(iii) From BF_t to E_t	
$H_0 : \alpha_{21} = b_{21} = 0$	*LR*=4.229 [0.120]	$H_0 : \alpha_{21} = b_{21} = 0$	*LR*=12.913 [0.001]

Note: See notes to Table 2.

Table 7

The estimated bivariate GARCH–BEKK–in–mean model for the UK.

Panel A: Exchange rates (E_t) and equity flows (EF_t)			Panel B: Exchange rates (E_t) and bond flows (BF_t)		
	E_t (i=1)	EF_t (i=2)		E_t (i=1)	BF_t (i=2)
Conditional Mean Equation					
μ_i	-0.060 (0.202)	0.239^{*} (0.139)	μ_i	-0.370^{*} (0.194)	1.334^{***} (0.185)
$\psi_{2i,t-1}$	–	0.186^{***} (0.054)	$\psi_{1i,t-1}$	–	0.342^{***} (0.109)
$\psi_{2i,t-2}$	–	0.096^{*} (0.051)	$\eta_{2i,t-2}$	-0.052^{**} (0.025)	–
$\psi_{2i,t-3}$	–	0.156^{***} (0.048)			
$\eta_{2i,t-3}$	-0.028^{*} (0.017)	–			
Conditional Variance Equation					
c_{1i}	0.659^{***} (0.146)	0	c_{1i}	0.290^{*} (0.160)	0
c_{2i}	-1.133^{***} (0.052)	0.00002 (0.272)	c_{2i}	0.173^{***} (0.041)	0.000002 (0.063)
α_{1i}	0.294^{***} (0.070)	0.032 (0.040)	α_{1i}	0.265^{**} (0.139)	0.070^{*} (0.040)
α_{2i}	-0.074 (0.154)	-0.226^{**} (0.097)	α_{2i}	-0.039 (0.067)	-0.001 (0.036)
b_{1i}	0.899^{***} (0.027)	0.023 (0.040)	b_{1i}	0.968^{***} (0.038)	-0.066^{***} (0.009)
b_{2i}	0.502^{***} (0.056)	0.468^{***} (0.003)	b_{2i}	0.324^{***} (0.088)	0.922^{***} (0.022)
Loglik	-1172.155		*Loglik*	-1078.105	
$Q(6)$	16.962 [0.850]	$Q^2(6)$ 8.996 [0.989]	$Q(6)$	21.022 [0.637]	$Q^2(6)$ 27.405 [0.157]
$Q(12)$	40.318 [0.776]	$Q^2(12)$ 24.90 [0.993]	$Q(12)$	38.397 [0.837]	$Q^2(12)$ 39.612 [0.698]

Tests of No Volatility Transmission:		Tests of No Volatility Transmission:	
(i) Bidirectional between E_t and EF_t		(i) Bidirectional between E_t and BF_t	
$H_0 : \alpha_{12} = \alpha_{21} = b_{12} = b_{21} = 0$	LR=4.181 [0.381]	$H_0 : \alpha_{12} = \alpha_{21} = b_{12} = b_{21} = 0$	LR=20.154 [0.000]
(ii) From E_t to EF_t		(ii) From E_t to BF_t	
$H_0 : \alpha_{12} = b_{12} = 0$	LR=1.161 [0.559]	$H_0 : \alpha_{12} = b_{12} = 0$	LR=33.733 [0.000]
(iii) From EF_t to E_t		(iii) From BF_t to E_t	
$H_0 : \alpha_{21} = b_{21} = 0$	LR=2.866 [0.238]	$H_0 : \alpha_{21} = b_{21} = 0$	LR=6.7430 [0.034]

Note: See notes to Table 2.