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John Beirne, Guglielmo Maria Caporale and Nicola Spagnolo

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INTEREST AND EXCHANGE RATE RISK AND STOCK RETURNS: A MULTIVARIATE GARCH-M MODELLING APPROACH

John Beirne, Guglielmo Maria Caporale[1] and Nicola Spagnolo

Centre for Empirical Finance, Brunel University, London

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Abstract

In this paper we examine the sensitivity of stock returns to market, interest rate, and exchange rate risk in three financial sectors (Banking, Financial Services and Insurance) in 16 countries, including various European economies, the US and Japan. We also test for the presence of causality-in-mean and volatility spillovers. The econometric framework is a four-variate GARCH-in-mean model, which incorporates long-and short-term interest rates in turn. We find in most cases a positive effect of stock market returns on mean returns in each sector; by contrast, interest rates and exchange rates have a significant effect only in a few cases, respectively negative and without a clear sign pattern. As for the three types of risk, these are found to play a role in a minority of cases, with mixed signs. Finally, most cases of volatility spillovers occur from market return to sectoral returns in the insurance and banking sector in European economies, though there are also some instances of interest rate and exchange rate spillovers, both in Europe and the *US*.

Keywords: *Interest rate, Volatility, Exchange rate, Multivariate GARCH*

JEL classification: *C32, G12*

[1] ***Corresponding author:*** *Professor Guglielmo Maria Caporale, Centre for Empirical Finance, Brunel University, Uxbridge, Middlesex UB8 3PH, UK. Tel. +44 (0)1895203327. Fax: +44 (0)1895 269 770. E-mail:* Guglielmo-Maria.Caporale@brunel.ac.uk

1. Introduction

Our aim is to investigate the sensitivity of stock returns to both interest and exchange rate risk in a number of European countries (including both EMU and non-EMU economies), as well as in the US and Japan. Both types of risk in recent years have attracted the attention of financial managers, agents, and policy makers in addition to academics. The latter type has become more important over time, as a result of the advent of flexible exchange rates in the 1970s, and the much higher degree of integration of financial markets. Its relevance was first highlighted in an equilibrium asset pricing context by Solnik (1974), who also showed that hedging or a short position in foreign bonds could reduce it. In the case of the member countries of the European Monetary Union (EMU) exchange rate exposure has presumably decreased since the introduction of a common currency (the euro) in January 1999. We conduct the analysis for three different financial sectors (Banks, Financial Services and Insurance), and interpret the results on the basis of the micro international banking model of Choi et al (1992).

The theoretical basis for our analysis is a multifactor model describing stock returns. The empirical framework is a four-variate GARCH-M model. Our contribution is twofold. First, the coverage of our study: ours is the most comprehensive comparative investigation to date in this area of the literature, as it includes Europe, US and Japan, and it provides evidence for three different financial sectors (Banks, Financial Services and Insurance). Most other studies focus on a single country, financial sector, or type of risk (see, e.g., Bae, 1990, Elyasiani and Mansur, 1998); studies allowing for both types of risk mainly analyse the US and the banking sector (see, e.g., Choi et al, 1992). Second, we carry out our extensive analysis using an appropriate econometric methodology (a four-variate GARCH-M framework) which enables us to model jointly the financial sector, the stock market, the interest rate and the exchange rate risk by estimating their conditional volatilities; by contrast, earlier studies, often only consider variables in levels (see again Choi et al, 1992 for the US) or changes in the level of interest and/or exchange rates (see, e.g., Di Iorio et al, 2006 for Europe). Koch and Saporoschenko (2001) estimate a AR(1)-GARCH(1,1) volatility model to analyse the effect of both interest and exchange rate risk, but only for Japanese financial firms.

Early contributions mainly focused on interest rate factors, and invariably assumed constant variance (see, e.g., Stone, 1974, Chance and Lane, 1980, and Bae, 1990). Choi et al (1992) included exchange rate risk as well. Following new developments in econometrics, the use of ARCH/GARCH-type models to account for time variation in the conditional variance became common. Examples are Song (1994), Flannery et al (1997), etc. Elyasiani and Mansur (1998) were the first to analyse bank returns by using a GARCH-M specification, in which the mean of returns is explicitly affected by the conditional variance, the effects of time-varying risk premia being incorporated into the model in this way. A similar framework was adopted by Brewer et al (2006) to analyse equity values of life insurance companies. A multivariate GARCH approach is followed by Elyasiani and Mansur (2004). These authors investigate the sensitivity of bank stock returns in the US to short- and long-term interest rates in turn. Multi-country studies on interest rate sensitivity include Flannery and James (1984), Neuberger (1991) and Madura and Zarruk (1995). The role exchange rate risk is instead investigated by, inter alia, Bodnar and Gentry (1993), Choi and Prasad (1995), Di Iorio and Faff (2000). A few studies combine both interest and exchange rate risk (see, e.g., Choi et al, 1992; Choi and Elyasiani, 1997; Koch and Saporoschenko, 2001; and Joseph, 2003).

Di Iorio et al (2006) consider both interest and exchange rate risk and their effects on financial sector returns in several euro zone and non-euro zone countries. Theirs is an augmented market model, in which returns are regressed against a constant, the return on the market index, the hold period return on a debt security, and exchange rate changes. Therefore volatility is not modelled.

Stock returns sensitivity to different types of risk can be theoretically justified in terms of risk aversion: essentially, a higher return is demanded by risk averse investors in the presence of risk factors other than those associated to the market portfolio (see, e.g., Merton, 1973). One can assume an explicit two- or multi-factor model based on the Arbitrage Pricing Theory (APT) developed by Ross (1976). If there are no arbitrage opportunities and the relationship between expected returns and risk premia is linear, an equilibrium relationship can be derived between returns, market factors, and other types of risk. The restrictions which can then be tested concern both sensitivity to risk exposure, and equilibrium pricing of risk. Alternatively, one can consider a more general model, which simply assumes returns to be a function of a set of variables (including market variables, changes in interest and exchange rates etc.), and test their significance. The advantage of the latter approach, which we follow in our study, is that it can more easily accommodate time-varying conditional volatilities.

The layout of the paper is the following. Section 2 describes the econometric model and the estimation approach. Section 3 presents the empirical evidence and interprets it. Section 4 summarises the main findings and offers some concluding remarks.

2. Methodology

We model the joint process governing the financial sector index, the stock market index, the interest rate and the US dollar bilateral exchange rates with a four-variate VAR-GARCH(1,1)-in-mean model[2]. In its most general specification the model has the following form:

$$x_t = \alpha + \beta x_{t-1} + \gamma H_t^{1/2} + u_t \qquad (1)$$

where x_t = (*fin - returns*$_t$, *stock - returns*$_t$, *interest*$_t$, *ex-rate*$_t$) and the residual vector $u_t = (e_{1,t}, e_{2,t}, e_{3,t}, e_{4,t})$ is four-variate and normally distributed $u_t \mid I_{t-1} \sim (0, H_t)$ with its corresponding conditional variance covariance matrix given by:

$$H_t = \begin{vmatrix} h_{11t} & h_{12t} & h_{13t} & h_{14t} \\ h_{21t} & h_{22t} & h_{23t} & h_{24t} \\ h_{31t} & h_{32t} & h_{33t} & h_{34t} \\ h_{41t} & h_{42t} & h_{43t} & h_{44t} \end{vmatrix} \qquad (2)$$

The parameters specification of the mean return equation (1) is defined by the constant $\alpha = (\alpha_1, \alpha_2, \alpha_3, \alpha_4)$, the autoregressive term $\beta = (\beta_{11}, \beta_{12}, \beta_{13}, \beta_{14} \mid 0,\beta_{22},0,0 \mid 0,0,\beta_{33},0 \mid 0,0,0, \beta_{44})$ and the GARCH-in-mean term $\gamma = (\gamma_{11}, \gamma_{12}, \gamma_{13}, \gamma_{14} \mid 0,0,0,0 \mid 0,0,0,0 \mid 0,0,0, 0)$ which is appearing in the first equation only. The parameter matrices for the variance equation (2) are given by C_0, which is restricted to be upper triangular, and two matrices A_{11} and G_{11}. It should be noted that in our model there are nine zero restrictions in the latter two matrices, as we are only interested in testing for causality-in-variance (spillover) running from the stock market index (measured by a_{12}), interest rate (measured by a_{13}), and exchange rate (measured by a_{14})

[2] The model is based on the multivariate GARCH(1,1)-BEKK representation proposed by Engle and Kroner (1995).

volatility to the financial sector volatility. Therefore, the second moment will take the following form:

$$H_t = C`_0C_0 + \begin{vmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ 0 & a_{22} & 0 & 0 \\ 0 & 0 & a_{33} & 0 \\ 0 & 0 & 0 & a_{44} \end{vmatrix}` \begin{vmatrix} e_{1,t-1}^2 & e_{1,t-1}e_{2,t-1} & e_{1,t-1}e_{3,t-1} & e_{1,t-1}e_{4,t-1} \\ e_{2,t-1}e_{1,t-1} & e_{2,t-1}^2 & e_{2,t-1}e_{3,t-1} & e_{2,t-1}e_{4,t-1} \\ e_{3,t-1}e_{1,t-1} & e_{3,t-1}e_{2,t-1} & e_{3,t-1}^2 & e_{3,t-1}e_{4,t-1} \\ e_{4,t-1}e_{1,t-1} & e_{4,t-1}e_{2,t-1} & e_{4,t-1}e_{3,t-1} & e_{4,t-1}^2 \end{vmatrix} \begin{vmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ 0 & a_{22} & 0 & 0 \\ 0 & 0 & a_{33} & 0 \\ 0 & 0 & 0 & a_{44} \end{vmatrix}$$

$$\begin{vmatrix} g_{11} & g_{12} & g_{13t} & g_{14} \\ 0 & g_{22} & 0 & 0 \\ 0 & 0 & g_{33} & 0 \\ 0 & 0 & 0 & g_{44} \end{vmatrix}` H_{t-1} \begin{vmatrix} g_{11} & g_{12} & g_{13t} & g_{14} \\ 0 & g_{22} & 0 & 0 \\ 0 & 0 & g_{33} & 0 \\ 0 & 0 & 0 & g_{44} \end{vmatrix} \quad (3)$$

Equation (2) models the dynamic process of H_t as a linear function of its own past values H_{t-1} and past values of the squared innovations ($e_1^2{}_{,t-1}$, $e_2^2{}_{,t-1}$, $e_3^2{}_{,t-1}$, $e_4^2{}_{,t-1}$), allowing for own-market and cross-series influences in the conditional variance. The important feature of this specification is that it guarantees by construction that the covariance matrices in the system are positive definite.

Given a sample of T observations, a vector of unknown parameters[3] θ and a 4 x 1 vector of variables x_t, the conditional density function for the model (1)-(3) is:

$$f(x_t \mid I_{t-1}; \theta) = (2\pi)^{-1} \mid H_t \mid^{-1/2} \exp(- [u`_t (H_t^{-1}) u_t] / 2) \quad (4)$$

The log likelihood function is:

$$\text{Log-Lik} = \Sigma_{t=1}^{T} \log f\ (x_t \mid I_{t-1}; \theta) \quad (5)$$

3. Empirical Analysis

In this section we test for sensitivity of the stock returns in three financial sectors to market, interest rate, and exchange rate risk. Two specifications of the four-variate GARCH-in-mean model are considered, incorporating in turn long- and short-term interest rates.

3.1 Hypotheses Tested

A number of hypotheses are tested on the estimated parameters and a likelihood ratio test statistic (LR) is computed between the unrestricted and restricted models, where LR = $-2(L_R - L_U) \sim \chi(k)$. The tests undertaken include individual and joint hypotheses at degrees of freedom (k) in the range 1 to 2 depending on number of restrictions (k) considered. The main restrictions tested are (i) the effect of stock market returns, interest rates, and exchange rates on mean returns in each financial sector; (ii) the effect of changes in the second moment of stock market returns, interest rates, and exchange rates on mean returns in each financial sector; finally (iii) volatility spillovers from stock market returns, interest rate, and exchange rate

[3] Standard errors are calculated using the quasi-maximum likelihood method of Bollerslev and Wooldridge (1992), which is robust to the distribution of the underlying residuals.

returns to volatility of returns in each financial sector. The specific tests undertaken for each of the estimated GARCH-in-mean models are outlined below:

i) Tests of No GARCH-in-mean Effect

H1: No Market Return Volatility Effect in Mean; $\gamma_{12} = 0$.

H2: No Interest Rate Volatility Effect in Mean; $\gamma_{13} = 0$.

H3: No Exchange Rate Volatility Effect in Mean; $\gamma_{14} = 0$.

H1 to H3 test the sensitivity of the level of the relevant financial sector index return to volatility in market returns, interest rates, and exchange rates. Here we are interested in whether *mean* financial sector index returns (i.e. bank, financial, insurance) are sensitive to *changes* in market returns, interest rates and exchange rates.

ii) Tests of No Causality in Variance Effect

H4: No Market Return Volatility Spillover Effect; $a_{12} = g_{12} = 0$

H5: No Interest Rate Volatility Spillover Effect; $a_{13} = g_{13} = 0$

H6: No Exchange Rate Volatility Spillover Effect; $a_{14} = g_{14} = 0$

H4 to H6 test the sensitivity of *volatility* of each financial sector index returns to *shocks* in squared market returns, interest rates and exchange rates.

iii) Tests of No Causality in Mean Effect

H7: No Market Return Effect; $\beta_{12} = 0$.

H8: No Interest Rate Effect; $\beta_{13} = 0$.

H9: No Exchange Rate Effect; $\beta_{14} = 0$.

H7 to H9 test the sensitivity of financial sector index returns to market returns, interest rates and exchange rates.

3.2 Data Description

The four-variate GARCH-in-mean model is estimated for 16 countries. They are the following: Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Japan, the Netherlands, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States. For each country, three financial stock indices (Banking, Financial Services, Insurance) are regressed on a stock market index, interest rates and exchange rates. The exceptions are Belgium and Portugal where there exists no Insurance index data. We carry out analyses for both short-term interest rates and long-term interest rates for all countries with the exception of Greece, for which a long-term interest rate series was not available. Therefore, for thirteen countries, six GARCH-in-mean models are estimated, while four are estimated for each of the two countries that lack Insurance index data, and three are estimated for Greece. All in all, therefore, eighty-nine models are estimated in unrestricted form.

For each country, the variables collected include three financial sector indices, a market index, 90-day Treasury Bill rates, 10-year government bond yields, and US dollar bilateral exchange rates (denominated as the domestic currency per unit of US dollar)[4]. The data were obtained from the IMF's IFS (International Financial Statistics) and Datastream. Treasury Bill data for Denmark and the Netherlands are taken from the respective Central Bank databases.

The data frequency is monthly, ensuring a sufficiently high number of observations. Further, a lower frequency (e.g. quarterly) would not provide an adequate representation of volatility fluctuations, whilst a higher frequency (e.g. daily) would require settlements and clearing delays to be incorporated into the model, as these have been identified as significant explanatory variables for returns (Baillie and DeGennaro, 1990; Elyasiani and Mansur, 1998). The sample period varies depending upon data availability. For eight of the countries, it oges from 1986:8 to 2006:12. For the remaining eight countries it ranges between 1987:2 and 1993:1 to 2006:12. Sample periods for each country are reported in Table 1.

Insert Table 1 about here

For the exchange rate data, a time series was constructed for the currencies of the Eurozone members from 1999:1 to 2006:12 using the rate at which the pre-EMU currency was converted to the Euro and the Euro/US dollar rate. Thus, a single US dollar exchange rate series is obtained for each country over the period of estimation. The market indices selected for each country are as follows: AMI (Netherlands), ASE (Greece), ATX (Austria), BEL 20 (Belgium), CAC 40 (France), DAX (Germany), FTSE 100 (UK), IBEX 35 (Spain), ISEQ (Ireland), MIB 30 (Italy), NIKKEI 225 (Japan), OMX (Denmark), OMX (Sweden), PSI 20 (Portugal), SMI (Switzerland), and S&P 500 (US).

In the GARCH-M estimations, returns for the stock market and exchange rate data are generated by continuous compounding. This approach is consistent with previous studies such as Prasad and Rajan (1995) and Choi et al (1992). As for interest rates, we use the first difference transformation, following Sweeney and Warga (1986) and Elyasiani and Mansur (1998).

3.3 Empirical Results

A sample regression for the US financial services sector is presented in Table 2, while the relevant results for all the models estimated for the financial services, banking and insurance sectors are summarised in Tables 3, 4 and 5 respectively.

Table 2 shows that most of the variables in the US financial services sector model are significant, whether we consider short- or long-term interest rates. Concerning spillover effects, let us focus first on the coefficients $\beta_{12,}$ β_{13} and β_{14}, which correspond respectively to stock return, interest rate and exchange rate causality in mean effects in the conditional mean equation. We can see a negative and significant effect only from the exchange rate to the financial services sector (β_{14}). As for spillovers of stock market, interest rate and exchange rate volatility, measured respectively by $\gamma_{12,}$ γ_{13} and γ_{14}, we find a positive, significant effect from the stock market (γ_{12}) and the exchange rate (γ_{14}) to financial services. Interest rate volatility has no significant effect, whether short- or long-term interest rates are considered. Finally, there is a significant volatility spillover effect running from stock market returns (a_{21}) and short-term interest rate volatility (a_{31}) (note that there no priors based on theory on the sign).

[4] In the case of the US, the exchange rate used is the US dollar vis-à-vis the German DM.

Insert Table 2-5 about here

The results for all countries (see Tables 3-5) can be summarised as follows. In the vast majority of cases we find, as expected, a positive effect of stock market returns on mean returns in each sector; by contrast, interest rates have a significant, negative effect on the mean only in a few cases, mainly in the Scandinavian countries; as for exchange rates, causality in mean is also found only in a few cases (European economies, as well as the US and Japan), but without a clear sign pattern. Moving on to sensitivity to risk, stock market volatility appears to have significant positive effects only in a few cases and only in the financial services and banking sectors (again, mainly in the Scandinavian countries and Greece, in addition to the US and Japan). Interest rate volatility has a (negative) GARCH-in-mean effect in a similar set of countries, but also including other Southern European economies such as Spain and Portugal. Exchange rate volatility only affects the financial services and banking sectors, and in a minority of cases (predominantly in European countries), with mixed signs. Finally, most cases of volatility spillovers from market return to sectoral returns occur in the insurance and banking sectors in European economies, but they are not numerous; interest rate spillovers are also found only in a minority of cases (including European economies and the US), and are of similar frequency in the various sectors; the same applies to exchange rate spillovers (also including both European countries and the US).

Insert Table 3-5 about here

Unlike in the study of Di Iorio et al (2006), we do not find that specific financial sectors are more (less) sensitive to short-term (long-term) interest rates, neither do we find a weaker effect of exchange rates compared to interest rates on returns. Clearly, their findings are affected by the fact that only variables in levels are considered, whilst risk is not modelled. Of particular interest are the results concerning the exchange rate risk. As highlighted by Choi et al (1992) in the context of their micro international banking model, this can affect returns through two channels, one corresponding to the "translation risk" (a bank optimally choosing zero net foreign lending/borrowing will not want to expose itself to exchange rate fluctuations), the other to a combination of translation and "economic risks" resulting from foreign exposure. Both effects can be positive or negative, depending on whether the bank is a net lender or borrower. These authors find considerable variability in the sign and significance of the exchange rate risk, depending on various factors, though the relationship appears to be mainly negative before October 1979, and positive afterwards. This is interpreted in terms of the net position in foreign currency in the balance sheet of these institutions switching from positive to negative around that time. Such changes in the net foreign exposure presumably also account for the different signs we find in the financial sectors/countries under examination. Again, our findings, in the context of a model simultaneously allowing for level and variance effects, differ from those of De Iorio et al (2006), as we do not find a clear pattern, with exchange rate exposure being predominantly positive for the Euro countries and negative elsewhere.

4. Conclusions

In this paper we have examined the sensitivity of stock returns to market, interest rate, and exchange rate risk in three financial sectors (Banking, Financial Services and Insurance) in 16 countries, including various European economies, the US and Japan. We have also tested for the presence of causality-in-mean and volatility spillovers. The econometric framework used is a four-variate GARCH-in-mean model, which incorporates long-and short-term interest rates in turn. Both the extensive country coverage, and the careful (simultaneous) modelling of risk sensitivity, causality-in-mean and causality-in-variance effects differentiate the present study from earlier ones, normally focusing on a single country, financial sector, or type of risk (see, e.g., Bae, 1990, Elyasiani and Mansur, 1998), and/or only considering variables in levels (see Choi et al, 1992) or changes in the level of interest and/or exchange rates (see, e.g., Di Iorio et al, 2006).

Overall, the effects of stock market returns/risk are those one would expect. As for interest and exchange rates, the picture which emerges is not equally clear. Although interest rate effects are found to matter in a variety of cases, no distinct pattern is found, i.e. it is not obvious what sectors or countries exhibit greater or smaller sensitivity. This also holds for exchange rate effects, although in this case the observed pattern is more easily interpretable in terms of the foreign net position of the financial institutions concerned. This lack of a clear pattern is in contrast to the findings of earlier studies (see, e.g., Di Iorio et al, 2006), which, however, were vitiated by their not taking into account risk exposure. Finally, volatility spillovers also occur in a number of cases. Future research should aim to provide a more detailed explanation of our findings by investigating more closely the role of the balance sheet and other relevant factors affecting the various types of the financial institutions examined.

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Table 1: Sample Periods for each Country

Country	Sample Period	Observations
Austria	1986:8 – 2006:12	245
Belgium	1990:2 – 2006:12	203
Denmark	1990:1 – 2006:12	204
France	1987:8 – 2006:12	233
Germany	1986:8 – 2006:12	245
Greece	1988:2 – 2006:12	227
Ireland*	1986:8 – 2006:12	245
Italy	1993:1 – 2006:12	168
Japan	1986:8 – 2006:12	245
Netherlands	1986:8 – 2006:12	245
Portugal	1993:1 – 2006:12	168
Spain	1987:2 – 2006:12	239
Sweden	1986:8 – 2006:12	245
Switzerland	1988:8 – 2006:12	221
United Kingdom	1986:8 – 2006:12	245
United States	1986:8 – 2006:12	245

* The sample period for the Insurance Sector in Ireland is from 1989:12 to 2006:12, i.e. 205 observations.

Table 2: Bank Stock Return Sector Effects Estimated Four-Variate GARCH(1,1) model for the United States				
Parameters	**Short Interest rate**		**Long Interest rate**	
	Coefficient	*S.E.*	*Coefficient*	*S.E.*
β_{11}	0.342	0.003	0.396	0.005
β_{12}	0.753*	0.697	0.631*	0.597
β_{13}	-0.301*	0.291	-0.101*	0.111
β_{14}	-0.106	0.005	-0.108	0.005
γ_{12}	1.016	0.563	1.321	0.516
γ_{13}	0.347*	0.293	0.004*	0.003
γ_{14}	1.797	0.286	1.488	0.491
a_{11}	0.304	0.119	0.327	0.001
a_{22}	0.295	0.105	0.305	0.109
a_{33}	0.463	0.202	0.175	0.061
a_{44}	0.198	0.098	0.221	0.047
a_{21}	1.065	0.419	1.073	0.001
a_{31}	0.019	0.001	0.001*	0.001
a_{41}	0.107*	0.101	0.123*	0.094
g_{11}	-0.914	0.008	-0.892	0.056
g_{22}	0.953	0.061	0.949	0.009
g_{33}	-0.392	0.009	-0.794	0.103
g_{44}	0.487	0.013	0.561	0.008
g_{21}	-0.027	0.001	0.016	0.001
g_{31}	0.684	0.020	0.102*	0.101
g_{41}	-0.113*	0.109	-0.155*	0.149
Log-Lik	2208.987		2133.504	
$LB_{(10)}$	3.457		2.149	
$LB^2_{(10)}$	1.788		2.341	

Note: The model estimated is : $x_t = \alpha + \beta x_{t-1} + \gamma H_t^{1/2} + u_{t.}$, where x_t = (fin - $returns_t$, stock - $returns_t$, $interest_t$, ex-$rate_t$) and the residual vector $u_t = (e_{1,t}, e_{2,t}, e_{3,t}, e_{4,t})$ is four-variate and normally distributed $u_t \mid I_{t-1} \sim (0, H_t)$ with its corresponding conditional variance covariance matrix given by Equation 2. The parameters specification of the mean return (equation (1)) is defined by the constant $\alpha = (\alpha_1, \alpha_2, \alpha_3, \alpha_4)$, the autoregressive term $\beta = (\beta_{11}, \beta_{12}, \beta_{13}, \beta_{14} \mid 0,\beta_{22},0,0 \mid 0,0,\beta_{33},0 \mid 0,0,0, \beta_{44})$ and the GARCH-in-mean term $\gamma = (\gamma_{11}, \gamma_{12}, \gamma_{13}, \gamma_{14} \mid 0,0,0,0 \mid 0,0,0,0 \mid 0,0,0, 0)$ which is appearing in the first equation only.

* denotes insignificant values at 5% significance level. Standard errors (S.E.) are calculated using the quasi-maximum likelihood method of Bollerslev and Wooldridge (1992), which is robust to the distribution of the underlying residuals. The $LB_{(10)}$ and $LB^2_{(10)}$ are respectively the Ljung-Box autocorrelations test (1978) of ten lags in the standardised and standardised squared residuals. The covariance stationary condition is satisfied by all the estimated models with all the eigenvalues of $A \otimes A + G \otimes G$ being less than one in modulus

Table 3: Insurance Stock Returns Sector Effects
Four-Variate GARCH(1,1)-in-mean Parameter Estimates

Country	Model	Market return			Interest rate			Exchange rate		
		β_{12}	γ_{12}	a_{21}	β_{13}	γ_{13}	a_{31}	β_{14}	γ_{14}	a_{41}
Austria	Short rate						0.012			
	Long rate			0.916	-0.009					
Denmark	Short rate	0.529			-0.011					1.141
	Long rate	0.570								-1.226
France	Short rate	1.001				-1.053				
	Long rate	0.804		0.190	-0.019	-0.098				-1.003
Germany	Short rate	0.976								
	Long rate	0.931		0.124	-0.015			0.181		-1.011
Greece	Short rate	0.499								
	Long rate									n/a
Ireland	Short rate	0.898								-0.825
	Long rate	0.951		-0.063			0.009			
Italy	Short rate			0.987	-0.009					
	Long rate			0.945		-0.027	-0.011			0.284
Japan	Short rate	0.782								
	Long rate	0.817		0.217						
Netherlands	Short rate	0.777						0.303		
	Long rate	0.731					0.009			
Spain	Short rate	0.984		-0.294						-0.166
	Long rate	1.103		-0.200				-0.179		
Sweden	Short rate	1.549			-0.014		0.005			1.735
	Long rate	1.314					-0.028			-1.059
Switzerland	Short rate	1.129						-0.206		
	Long rate	1.157		0.204						
UK	Short rate	1.190		0.584						
	Long rate	1.147					-0.002			0.054
US	Short rate	0.802		0.036			0.029			
	Long rate	0.810				-0.099	-0.019			0.335

Note: See notes Table 2. Blank cells denote insignificant values.

Table 4: Financial Stock Returns Sector Effects
Four-Variate GARCH(1,1)-in-mean Parameter Estimates

Country	Model	Market return			Interest rate			Exchange rate		
		β_{12}	γ_{12}	a_{21}	β_{13}	γ_{13}	a_{31}	β_{14}	γ_{14}	a_{41}
Austria	Short rate	0.172								
	Long rate	0.092		0.146						
Belgium	Short rate									-0.104
	Long rate	0.956		-0.085					1.076	
Denmark	Short rate			0.162		-0.468			-0.398	
	Long rate		0.345	0.852	-0.005	-0.021				1.318
France	Short rate									
	Long rate			0.239		-0.963	-0.007		-1.094	
Germany	Short rate			1.136				-0.165		
	Long rate			1.049			-0.012	-0.202	1.864	0.601
Greece	Short rate		0.476	0.965		-0.096	0.005		0.357	
	Long rate									n/a
Ireland	Short rate			0.616				-0.212		0.894
	Long rate			0.153		-0.076	-0.009	-0.161		-0.343
Italy	Short rate						-0.012			
	Long rate					-0.024		0.407		
Japan	Short rate		1.511	-1.85				-0.254	1.615	-0.252
	Long rate		0.544	0.96				-0.241	-3.931	-0.196
Netherlands	Short rate			0.869				0.312		
	Long rate		0.614		-0.009	-0.103	-0.005	0.331	1.249	
Portugal	Short rate	0.260				-0.005				0.586
	Long rate	0.292		0.772						
Spain	Short rate			0.442						
	Long rate			0.259						
Sweden	Short rate		1.638	1.161	-0.007	-0.021				
	Long rate	0.209		0.159						
Switzerland	Short rate	0.185		0.213					1.609	
	Long rate	0.283		1.793		-0.098				0.035
UK	Short rate		1.895	1.558		-0.108				
	Long rate									0.149
US	Short rate		1.016	1.065			0.019	-0.106	1.797	
	Long rate		1.321	1.073				-0.108	1.488	

Note: see notes Table 3.

Table 5: Bank Stock Returns Sector Effects
Four-Variate GARCH(1,1)-in-mean Parameter Estimates

Country	Model	Market return			Interest rate			Exchange rate		
		β_{12}	γ_{12}	a_{21}	β_{13}	γ_{13}	a_{31}	β_{14}	γ_{14}	a_{41}
Austria	Short rate	0.142		-0.037			0.017		1.468	-0.248
	Long rate			-0.039		-0.013			-1.375	-0.327
Belgium	Short rate	1.103		0.253		-1.560				
	Long rate	0.972					0.017	-0.201		0.596
Denmark	Short rate	0.809				-0.642	-0.006			
	Long rate	0.744				-0.008				
France	Short rate	0.974								
	Long rate	0.913	0.936	0.103		-0.216			1.891	
Germany	Short rate	0.813					-0.049			
	Long rate	0.802								
Greece	Short rate		0.483	0.933		-0.094	0.006			
	Long rate									n/a
Ireland	Short rate	1.059								
	Long rate	1.016								1.411
Italy	Short rate			-0.126	-0.003	-0.106			-0.291	
	Long rate			0.183		-0.019			-1.220	
Japan	Short rate	0.865						-0.318		
	Long rate	0.854								-0.482
Netherlands	Short rate	0.755		-0.196						0.296
	Long rate	0.719			-0.019		-0.041			
Portugal	Short rate	0.823								
	Long rate	0.792								
Spain	Short rate	0.959					-0.014			
	Long rate	0.913		-0.201		-0.022	-0.008			
Sweden	Short rate	0.799								
	Long rate	0.865		0.072	-0.027	-0.043				0.438
Switzerland	Short rate	0.981	1.268	-0.196		-0.397		-0.099	1.801	
	Long rate	0.949		-0.297		-0.965				
UK	Short rate	1.113		-0.686						0.339
	Long rate	1.122					0.059			
US	Short rate	0.087								
	Long rate	0.102	0.839				0.017			

Note: see notes Table 3.