Foreign exchange risk premiums and time-varying equity market risks

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Abstract: This paper investigates the relationship between the excess returns of foreign exchanges and the conditional volatility of domestic and foreign equity markets, based on a wide range of foreign currency market data. Utilising a VAR-GARCH-in-mean process to generate conditional variances, we find evidence to support the time varying, risk-premium hypothesis. Moreover, our evidence shows that the volatility evolution of stock returns displays not only a clustering phenomenon, but also a significant spillover effect. Given the fact that the correlation structure across markets is significant and time varying, investors and portfolio managers should continually assess this information and rebalance their portfolios over time to achieve optimal diversification.

Keywords: exchange rate risk; risk premiums; multivariate GARCH; volatility.

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1 Introduction

By now a considerable amount of empirical evidence has demonstrated that the unbiasedness hypothesis using forward exchange rate to predict the subsequent spot exchange rates is rejected. Although the sources of rejection have been attributable to market imperfections, the existence of transaction costs, measurement errors, expectations errors, and/or the lack of more powerful statistical techniques, the main concern is the significance of risk factors [1,2]. By focusing on pricing risk, the literature has advanced along three different tracks. The first approach is derived from the consumption-based model in the vein of Lucas [3] asset pricing framework. The risk is seen to be captured by the conditional covariance of intertemporal marginal rates of substitution of money and the profit from foreign exchange speculation. Research along this line includes Hodrick and Srivastava [4], Domowitz and Hakkio [5], Giovannini and Jorion [6], Cumby [7], Mark [8], and Backus, Gregory, and Telmer [9].

The second approach takes the route of the market-based Capital Asset Pricing Model (CAPM). A special feature of this approach is that currency market risk is seen to be proportional to market-excess returns. Thus, the model requires that profit derived from foreign exchange speculation should not be orthogonal to 'market' excess returns if the risk-premium hypothesis holds true. In their empirical investigations, Roll and Solnik [10] estimate the covariance between the 'extraordinary' exchange return and the 'index' of the exchange return; Robichek and Eaker [11] relate the exchange return to systematic risk; Chiang [12] and Morley and Pentecost [13] link forward-exchange profit to relative *ex ante* risk in equity markets; and Korajczyk and Viallet [14] test forward exchange market profit in relation to excess returns on the benchmark portfolio. All of these authors provide evidence to support this risk-premium hypothesis.

The third approach explores the time-series properties of conditional second moments of state variables. The risk in this type of model is captured by the conditional variance in ARCH-type specification [15,16] due to its capability of modelling clustering phenomenon of exchange rate volatility. Risk specifications based on conditional variance [4–6,17,18] offer supporting evidence in favour of conditional variance as a risk factor. Due to the fact that different authors use different information, such as interest rates, real output, exchange rates, or money supply, to generate conditional variance, the results on conditional variance models vary somewhat among the different researchers. Using larger information sets by including determinants of the monetary model, Cheung [19] can find only limited support for the risk-premium hypothesis. Thus, no concrete evidence has been consistently in favour of conditional-variance models.

Building on the empirical evidence, this paper is another attempt to examine the relationship between foreign exchange speculative profit and risk factors. Our study is motivated by three recent empirical developments in asset markets. Firstly, the evidence shows that foreign exchange profit is related to excess stock returns [12]; both foreign exchange and stock excess returns are commonly correlated with nominal interest rates [6] and dividend yields [20]. Secondly, risk-averse behaviour suggests that the expected excess returns on assets are tied closely to expected risk premiums, and the latter are thought to covary with conditional volatility. Findings by Merton [21] and French, Schwert, and Stambaugh [22] indicate a positive relationship between stock market returns and conditional variance. Thirdly, evidence shows that exchange rates tend to be highly volatile. This exchange rate volatility appears to be higher than that of the fundamental factors on which they depend, including money supply, real income, and inflation rate [23]), suggesting that conditional volatility may be more effectively predicted by using stock-return volatility.

On the basis of these empirical regularities, we perform a direct test relating the speculative profit in foreign exchange markets to conditional volatilities in stock markets. This paper differs from previous studies in several aspects. Firstly, instead of relating the foreign exchange risk premium to expected equity premiums, the model directly relates the foreign exchange premium to conditional variances of domestic and foreign equity markets. Secondly, we employ a VAR-GARCH-in-mean process to model and generate the time-varying conditional second moments. A parsimonious parameterisation of the multivariate GARCH process which imposes the covariance matrix to be positive definite will be used to model the conditional covariance matrix of the error process. The model is capable of capturing the dynamic relationship, for both the conditional first and second moments, between domestic and foreign equity market returns. Thirdly, the sample includes a wide range of currencies from January 1979 through December 1998 to capture roughly the recent 20-year experience of floating exchange rates [24]. Finally, as mentioned by Baillie and Bollerslev [25], it is important to have high-frequency data in order to detect relatively short-lived risk premiums or market inefficiencies (e.g., [26,27]). However, it is well known that when the sampling interval is finer than the forecast interval, forecast errors will be serially correlated. Thus, we use weekly data and employ a Hansen and Hodrick [26] technique to correct the overlapping data problem in order to examine the changing expectations of investors in international financial markets. Our empirical evidence indicates that foreign exchange risk premiums are significantly correlated with the time-varying risk of national stock markets. This suggests that one can gain more insight into speculative-profit behaviour if the cross-asset variance structural relationship is considered.

The remainder of the paper is organised as follows. Section 2 discusses the theoretical framework that links the forward foreign exchange risk premium to relative stock-market risk. Section 3 describes the data and estimation procedures of the model. Section 4 reports the empirical results. Section 5 contains a summary and concluding remark.

2 Theoretical framework

In the absence of capital controls, with low transaction costs and a high degree of arbitrage between markets, the expected return on asset j in the domestic country should equal to the expected return on an asset with similar risk characteristics in the foreign country plus the expected rate of depreciation of the domestic currency over a given period of time. This implies that nominal expected returns in the domestic country would be equal to the expected nominal returns in the foreign country measured in domestic currency; that is:

$$E\left(R_{j,t+1} \mid I_t\right) = E\left(R^*_{j,t+1} \mid I_t\right) + E\left(R_{s,t+1} \mid I_t\right), \quad (1)$$

where $E\left(R_{j,t+1}\right)$ is the expected required rate of return on asset j at time t+1; $E\left(R_{s,t+1}\right)$ is the expected rate of depreciation of the domestic currency from time t to time t+1; $E\left(\cdot \mid I_t\right)$ is the expectation operator conditional on the information set I at time t; and an asterisk denotes a foreign variable. The market-based CAPM implies that the expected excess return for asset j in the domestic capital market is a linear combination of the risk premiums of the domestic and foreign equity markets. The specification is given by:

$$E\left(R_{j,t+1} \mid I_t\right) - r_t = \beta_{j1}\left[E\left(R_{m,t+1} \mid I_t\right) - r_t\right] + \beta_{j2}^{*}\left[E\left(R_{m,t+1}^{*} \mid I_t\right) - r_t^{*}\right], \tag{2}$$

$$E\left(R_{j,t+1}^{*} \mid I_t\right) - r_t^{*} = \beta_{j1}^{*}\left[E\left(R_{m,t+1}^{*} \mid I_t\right) - r_t^{*}\right] + \beta_{j2}\left[E\left(R_{m,t+1} \mid I_t\right) - r_t\right], \tag{3}$$

where R_m denotes the national equity-market return and r_t denotes the risk-free interest rate. Equation (2) and equation (3) are similar to the static capital asset pricing model (CAPM) of Sharpe [28] and Lintner [29]. However, in the international setting, an additional term (the last term of the equations) is incorporated into the model to capture the risk factors associated with the external markets [30].

Combining equation (1) through to equation (3) and summing over all assets *j,* we obtain an aggregate representation as:

$$\left[E\left(s_{t+1} \mid I_t\right) - s_t\right] - \left(r_t - r_t^{*}\right) = \beta\left[E\left(R_{m,t+1} \mid I_t\right) - r_t\right] - \beta^{*}\left[E\left(R_{m,t+1}^{*} \mid I_t\right) - r_t^{*}\right], \tag{4}$$

where $\left[E\left(s_{t+1} \mid I_t\right) - s_t\right] = E\left(R_{s,t+1} \mid I_t\right)$, and $E\left(s_{t+1} \mid I_t\right)$ and s_t are the natural logarithm of expected future and current spot exchange rates, respectively. Equation (4) represents an equilibrium condition that links the expected excess return in the foreign exchange market to the relative risk, reflected in the relative expected-risk premiums in the domestic and foreign equity markets [31]. In this specification, β and β^{*} are equally weighted averages of their respective $\beta_j{}'s$ in the domestic and foreign equity markets.

By applying (i) Merton's [32] intertemporal asset pricing framework that links the equity-risk premium to the conditional variance of the relevant equity portfolio as equations (5) and (5)′ and (ii) the covered interest-rate parity condition, $f_t - s_t = r_t - r_t^{*}$, we obtain a reduced form equation given by (6):

$$E\left(R_{m,t+1} \mid I_t\right) - r_t = \lambda E\left(\sigma_{m,t+1}^{2}\right) \tag{5}$$

$$E\left(R_{m,t+1}^{*} \mid I_t\right) - r_t^{*} = \lambda^{*} E\left(\sigma_{m,t+1}^{*2}\right) \tag{5$'$}$$

$$\left[E\left(s_{t+1} \mid I_t\right) - f_t\right] = \gamma E\left(\sigma_{m,t+1}^{2}\right) - \gamma^{*} E\left(\sigma_{m,t+1}^{*2}\right), \tag{6}$$

where $\left[E\left(s_{t+1} \mid I_t\right) - f_t\right]$ is the nominal speculative profit from the forward contract; f_t is the natural algorithm of forward exchange rate; λ is the coefficient of relative risk-aversion; $E\left(\sigma_{m,t+1}^{2} \mid I_t\right)$ is the conditional variance of the national equity market return; and $\gamma = \beta\,\lambda$ ($\gamma^{*} = \beta^{*}\lambda^{*}$) is a positive parameter if the market is dominated by domestic forces in each country. *A priori*, it is expected that a positive relationship exists between *ex ante* returns and conditional volatility of returns. Here we do not restrict the

γ coefficient to be positive because the functional relationship between the first two moments of returns does not have to be positive as evidenced by Glosten *et al.* [33].

Equation (6) conveys two important messages. Firstly, the concept of relative risk is emphasised, which differs from the previous models by using single-market risk (e.g., Roll and Solnik [10], Robichek and Eaker [11], and Mark [8], [34]). Secondly, the model directly links foreign exchange profits to equity risk premiums and, in turn, to the expected variance of equity returns, which extends the capital asset pricing model to an international setting [35].

The model is consistent with the notion that the exchange rate is the relative price of two national currencies; its excess return ought to covary with the relative risk of assets of the two trading countries. In highly integrated capital markets, the relative conditional variance in the national equity markets provides systematic information to the *ex ante* risk involving international investments. Therefore, we establish a relationship between the speculative profit in the forward exchange market and the risk factors associated with national equity markets [36].

3 Description of data, basic statistics, and empirical estimations

To start with, we describe the data, basic statistics, and some econometric issues related to the data construction. In the light of recent findings that national stock markets are highly integrated, domestic and foreign stock-market returns are assumed to follow a VAR process with bivariate GARCH-in-mean innovations [15,16]. These conditional GARCH models have been empirically shown to provide a good fit for modelling the volatility evolution of many financial return series.

3.1 Description of data and basic statistics

The stock market indices studied are those of Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Spain, Switzerland, Sweden, the UK, and the USA. All the indices are weekly observations of Friday closing prices expressed in local currency values and are obtained from *Datastream International*. Spot exchange rates and one-month forward rates are taken from the WEFA group. The exchange rates are weekly Friday closing quotations and are expressed in national currency units (NCU) per US dollar, including Belgian francs, Canadian dollars, French francs, Deutsche marks, Italian lira, Japanese yen, Dutch guilders, Spanish pesetas, Swedish krona, Swiss francs, and British pounds. The sample spans a time frame from 1979/01/05 through to 1999/01/08 to cover a 20-year experience with floating exchange rates. The ending date of the sample is dictated by the availability of the data [37].

The weekly stock return is defined as the natural log-difference of weekly stock prices. The monthly forward-rate forecast errors, $s_{t+4} - f_t$, are generated weekly, where s_t and f_t denote the natural logarithm of the spot exchange rate and the corresponding forward exchange rate, respectively. The justification for using a weekly sampling scheme is twofold. Firstly, in testing foreign exchange market efficiency or rational expectations, the use of non-overlapping samples can circumvent problems with serial correlation, but at the expense of not utilising all available observations in the process [26]. The overlapping sample provides more information for our empirical investigation. Secondly, it is important to have high-frequency data in order to detect relatively short-lived risk premiums or market inefficiencies, as noted by Baillie and Bollerslev [25]. However, it is well known that when the sampling interval is finer than the forecast interval, forecast errors will be serially correlated. Hansen and Hodrick [26] develop a generalized method of moment approach to deal with this issue. They prove that using overlapping data with the GMM estimator is superior to sampling a non-overlapping data set to which ordinary least squares and traditional computation of the asymptotic covariance matrix are applied directly.

Table 1 reports basic time-series properties of the data. The Japanese stock market has the smallest return (0.08%) and the Italian market has the highest return (0.33%) in the sample period. For the standard deviation, the Swiss market has the smallest value (1.96%), whilst Italy shows the highest one (3.32%). Most of the distributions are skewed to the left and have heavy tails. Except for Germany, the kurtosis coefficients are all larger than those of the standard normal distribution. The serial correlations of the return levels are significant for most of the countries, and the Ljung-Box Q(4) tests with four lags are uniformly rejected, indicating the non-randomness of the return series. The only exception is the US market. Looking at the Ljung-Box $Q^2(4)$ statistics, the evidence shows that the return squares display non-linear dependency for all markets. The statistics thus decisively suggest that the independence of the level and of the squares for the return series is rejected consistently by the data. Our empirical experience suggests that the linear dependency could result from market imperfections or sluggish adjustments, whilst non-linear dependency could stem from autoregressive conditional heterokedasticity (ARCH). The coexistence of serial correlation of returns and conditional heterokedasticity suggests that return series is predictable and the volatilities are time varying.

3.2 Empirical estimations

To implement the empirical estimation of the proposed model, we adopt a two-step estimation strategy. Firstly, due to the mounting empirical evidence that national stock markets are highly integrated and display conditional volatility, we estimate the stochastic process of the two national stock markets (country *i* with respect to the USA) by using a VAR process with bivariate GARCH innovations for each of the country with respect to the US market [38–44]. Secondly, we use the estimated conditional variances from the VAR-GARCH-in-mean process as proxies for the conditional variances of national stock market returns to test equation (6). Pagan [45] examines the consistency and asymptotic distribution of such a strategy and demonstrates that if the first step produces a consistent estimate of the true conditional variance and covariance, the procedure will produce consistent estimates of the parameters of interest.

Table 1 Summary statistics of national stock-market returns and *ex post* speculative profits on forward-currency contracts

Country	*Belgium*	*Canada*	*France*	*Germany*	*Italy*	*Japan*
A. National stock-market returns:						
Mean	0.0022	0.0016	0.0025	0.0021	0.0033	0.0008
Std. dev.	0.0208	0.0202	0.0261	0.0243	0.0332	0.0243
Skewness	–0.11	–0.61***	–0.72***	–0.46***	–0.08	–0.26***
Kurtosis	8.39***	4.86***	5.62***	2.79***	6.25***	3.66***
ρ_1	0.0864	0.1194	0.1147	0.0443	0.0632	-0.0255
ρ_2	0.1824	0.0661	0.0985	0.0841	0.0610	0.0817
ρ_3	0.0555	0.0616	0.0536	0.036	0.0886	0.0364
ρ_4	0.0337	0.0334	0.0237	0.0147	0.0299	-0.0173
$Q(4)$	47.15***	24.66***	27.55***	11.07**	17.27***	9.38*
ρ_1^2	0.0745	0.1466	0.077	0.1504	0.3121	0.2084
ρ_2^2	0.1405	0.1346	0.1208	0.3577	0.0388	0.1494
ρ_3^2	0.0362	0.0529	0.1904	0.0803	0.1238	0.2008
ρ_4^2	0.0277	0.0383	0.0355	0.1342	0.0533	0.1591
$Q^2(4)$	28.70***	46.00***	60.90***	183.57***	122.72***	137.86***
B. Ex post speculative profits on forward-currency contracts:						
Mean	–0.0001	0.0001	0.0002	0.0012	–0.0016	0.0007
Std. dev.	0.0318	0.0126	0.0359	0.032	0.031	0.0342
Skewness	–0.01	0.23***	3.90***	–0.03	0.41***	–0.62***
Kurtosis	0.28*	0.48***	61.62***	0.18	1.71***	0.91***
ρ_1	0.7800	0.7426	0.5563	0.7805	0.7713	0.7997
ρ_2	0.5699	0.4946	0.3902	0.5533	0.5516	0.6012
ρ_3	0.3414	0.2494	0.2395	0.3139	0.3258	0.3842
ρ_4	0.1075	-0.0119	0.0967	0.0795	0.0888	0.1611
$Q(4)$	207.71***	396.66***	551.63***	164.69***	157.44***	227.14***
ρ_1^2	0.5831	0.5338	0.1164	0.5751	0.6219	0.6738
ρ_2^2	0.3317	0.2803	0.1074	0.2928	0.3625	0.4351
ρ_3^2	0.1397	0.1142	0.0038	0.1126	0.1788	0.1912
ρ_4^2	0.0049	0.1275	0.0006	0.0080	0.0541	0.1042
$Q^2(4)$	89.98***	41.28***	13.58*	47.94***	77.16***	72.61***

The data set is constructed from a daily frequency by taking Friday's observations, and it covers the period 1979:1:5 to 1999:1:8 for most countries. The weekly stock returns are log-differences of the stock-market index and the weekly 1-month speculative profits on forward-currency contracts are log-differences between the current spot rate and forward rate observed four weeks earlier. ρ_i and ρ_i^2 are the i-order serial correlations of returns and squared returns, respectively, whilst $Q(4)$ and $Q^2(4)$ are the Ljung-Box statistics with 4 lags. The standard deviation of the correlations is approximately $n^{-0.5} = 0.03$ ($n = 1040$, for most cases).

The *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 1 Summary statistics of national stock-market returns and *ex post* speculative profits on forward-currency contracts (continued)

Country	*Netherlands*	*Spain*	*Switzerland*	*Sweden*	*UK*	*US*
A. National stock-market returns:						
Mean	0.0026	0.0028	0.0020	0.0034	0.0024	0.0025
Std. dev.	0.0217	0.0266	0.0196	0.0269	0.0218	0.0201
Skewness	–0.64***	–0.16**	–1.40***	–0.14*	–1.44***	–0.45***
Kurtosis	4.24***	5.70***	11.21***	4.47***	14.70***	3.07***
ρ_1	0.0542	0.1378	0.1693	0.1332	0.0561	–0.0197
ρ_2	0.1126	0.0973	0.1223	0.1187	0.1317	0.0508
ρ_3	–0.0113	0.1302	0.0341	0.1055	–0.0512	–0.0158
ρ_4	0.0715	–0.0147	0.0383	0.0038	0.0535	0.0006
$Q(4)$	20.81***	47.85***	48.50***	36.86***	27.27***	3.37
ρ_1^2	0.0995	0.2211	0.1908	0.2572	0.0474	0.2580
ρ_2^2	0.2785	0.1848	0.2467	0.0824	0.1083	0.1115
ρ_3^2	0.1553	0.0946	0.0574	0.0448	0.0174	0.0402
ρ_4^2	0.0923	0.0747	0.0650	0.1404	0.0107	0.0310
$Q^2(4)$	119.78***	102.34***	109.91***	81.19***	15.08***	85.50***
B. Ex post speculative profits on forward-currency contracts:						
Mean	0.0008	–0.0017	0.0021	0.0007	–0.0011	
Std. dev.	0.0329	0.0307	0.0355	0.0305	0.0315	
Skewness	–0.40***	0.22***	–0.22***	1.27***	0.06	
Kurtosis	2.54***	0.62***	0.07	5.47***	2.06***	
ρ_1	0.7369	0.7297	0.7718	0.7681	0.7795	
ρ_2	0.5334	0.5103	0.5589	0.5904	0.5432	
ρ_3	0.3108	0.2854	0.3351	0.4002	0.3193	
ρ_4	0.1097	0.0448	0.0937	0.1945	0.1079	
$Q(4)$	328.47***	214.62***	175.13***	170.38***	161.72***	
ρ_1^2	0.2315	0.4790	0.5626	0.7173	0.6934	
ρ_2^2	0.1183	0.2415	0.2837	0.5678	0.4265	
ρ_3^2	0.0456	0.1539	0.1088	0.4468	0.2218	
ρ_4^2	–0.0106	0.0472	–0.0109	0.2359	0.0975	
$Q^2(4)$	69.19***	127.35***	107.10***	132.65***	153.66***	

The data set is constructed from a daily frequency by taking Friday's observations, and it covers the period 1979:1:5 to 1999:1:8 for most countries. The weekly stock returns are log-differences of the stock-market index and the weekly 1-month speculative profits on forward-currency contracts are log-differences between the current spot rate and forward rate observed four weeks earlier. ρ_i and ρ_i^2 are the *i*-order serial correlations of returns and squared returns, respectively, whilst $Q(4)$ and $Q^2(4)$ are the Ljung-Box statistics with 4 lags. The standard deviation of the correlations is approximately $n^{-0.5} = 0.03$ ($n = 1040$, for most cases).

The *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Assuming that the bivariate GARCH process has an order of (*p,q*), the VAR process with bivariate GARCH-in-mean innovations can be written as:

$$\begin{bmatrix} R^{i}_{m,t} \\ R^{us}_{m,t} \end{bmatrix} = \begin{bmatrix} \phi_{10} \\ \phi_{20} \end{bmatrix} + \begin{bmatrix} \phi_{11}(L) & \phi_{12}(L) \\ \phi_{21}(L) & \phi_{22}(L) \end{bmatrix} \begin{bmatrix} R^{i}_{m,t} \\ R^{us}_{m,t} \end{bmatrix} + \begin{bmatrix} \phi_{13} \\ \phi_{23} \end{bmatrix} \begin{bmatrix} h^{i}_{m,t} \\ h^{us}_{m,t} \end{bmatrix} + \begin{bmatrix} \varepsilon^{i}_{t} \\ \varepsilon^{us}_{t} \end{bmatrix}, \tag{7}$$

$$\varepsilon_t \mid I_{t-1} \sim N\left[0, H_t(I_{t-1})\right],\ H_t = \begin{bmatrix} h_{11t} & h_{12t} \\ h_{22t} & h_{22t} \end{bmatrix}, \tag{8}$$

$$H_t = C + \sum_{k=1}^{q} u'_{t-k} D_k u_{t-k} + \sum_{k=1}^{p} G_k H_{t-k}, \tag{9}$$

where C, D_k, and G_k are 2×2 matrices. However, under this specification, H_t is not guaranteed to be positive definite for all values of u_t in the sample space. To overcome this problem, we adopt the parameterisation suggested by Baba *et al.* [46] which easily imposes these restrictions. By using the parameterization scheme, we can rewrite equation (9) as follows:

$$H_t = C'C + \sum_{k=1}^{q} D'_k u_{t-k} u'_{t-k} D_k + \sum_{k=1}^{p} G'_k H_{t-k} G_k, \tag{9$'$}$$

where the C, D, and G are 2×2 matrices, and C is symmetrical and restricted to be upper triangular. A specification test will be used to investigate the adequacy of this statistical model of the conditional covariance matrix, H_t. The conditional variance of each variable in (9)’ is related to past squared residuals and cross-residuals and past variances and covariances of variables involved.

Equation (7) to equation (9)′ can be estimated by maximum likelihood techniques. For sample size T, the log-likelihood function is the sum of the conditional log-likelihood for each observation:

$$L_T(\theta_f) = \sum_{t=1}^{T} \ell_t(\theta_f),$$

$$\ell_t(\theta_f) = -\ln(2\pi) - \frac{1}{2}\left(\ln|H_t|\right) - \frac{1}{2}\mu'_t H_t^{-1}\mu_t, \tag{10}$$

and this log-likelihood function can be maximized with respect to the unknown parameter θ_f (C, D, G) for the model which is a vector of all parameters to be estimated. Since the normality assumption is violated for the return series in the sample (Table 1) and this is often the case in financial time series, we adopt the quasi-maximum likelihood estimation (QML) proposed by Bollerslev and Wooldridge [47], which allows inference in the presence of departure from conditional normality. Under fairly weak conditions, the resulting estimates are consistent even when the conditional distribution of the residuals is non-normal. The QML estimates can be obtained by maximising equation (10) and by calculating a robust estimate of the covariance of parameter estimates using the matrix of second derivatives and the average of the period-by-period outer products of gradient. Non-linear optimization techniques are used to calculate the maximum likelihood estimates based on the Broyden, Fletcher, Goldfarb, and Shanno (BFGS) algorithm.

Having derived the conditional variances, we fit the speculative profit equation as follows:

$$s_{t+1} - f_t = \alpha_0 + \alpha_1 h_{11,t+1} + \alpha_2 h_{22,t+1} + \varepsilon_{t+1}\,. \tag{11}$$

Equation (11) examines whether the conditional variances of domestic and foreign stock market returns are significant in explaining the deviation of the forward rate from the future spot rate. The significance test can be done by using standard t-statistics. To avoid the stochastic-regressor problem [45], we adopt GMM [26] estimators to correct the serial correlation of the residuals and a possible heteroskedasticity problem of the dependent variables. It can be shown that the estimators of coefficients (α s) using generated regressors from the first stage are consistent, and the 'asymptotic *t*-statistics' and '*F*-test' are valid.

4 Empirical results

4.1 Correlations in price changes and volatilities across international stock markets

On the basis of significance tests on coefficients of the autocorrelation and cross-correlation functions [48], the VAR(2) is selected in our estimation. The estimates for the mean and variance equations are reported in Table 2 and Table 3, respectively.

4.1.1 Time-varying expected returns and mean spillover effects

The evidence in Table 2 shows that most of the national stock-index returns are predictable by using past information from the US and the domestic stock returns. Consistent with the existing evidence [38], the results indicate a statistically significant mean-spillover effect from the USA to the other markets in the sample period. They further confirm the dominant role of US market returns in determining returns of other markets. It should be noted that the existence of predictability of returns might be attributable to market imperfection, time-varying risk premiums, or market irrational behaviour.

4.1.2 Time-varying international market correlation and volatility spillover effects

The significance of the autocorrelations and Ljung-Box *Q*-statistics for the squared returns (Table 1) indicates a need to model the non-linear dependency for the return series. The VAR model with GARCH-in-mean innovations appears adequate to capture the stochastic process. Table 3 contains the coefficients of the VGARCH(1,1) process, the variance equation. The results may be summarized as follows. First, for most markets in the sample, the returns present significant conditional heteroskedasticity; the time-varying behaviour of the correlation structure of returns in a bivariate setting (each county with respect to the US market) is identified. Second, both variance and covariance terms in most cases are statistically significant, indicating the relevance of the vector GARCH model and the existence of a volatility-spillover effect across different markets.

Table 2 Estimation results of the bivariate GARCH (1,1) model for the stock returns [mean equation, (7)]

	ϕ_{10}	$\phi_{11}(1)$	$\phi_{12}(1)$	$\phi_{11}(2)$	$\phi_{12}(2)$	ϕ_{13}
Country	ϕ_{20}	$\phi_{21}(1)$	$\phi_{22}(1)$	$\phi_{21}(2)$	$\phi_{22}(2)$	ϕ_{23}
Belgium	–0.0019*	0.0577	0.1451***	0.1077**	0.0429	9.1960***
	(1.85)	(1.37)	(3.84)	(2.11)	(1.25)	(3.14)
US	0.0007	0.0341	–0.1034***	–0.0271	0.0461	6.3179*
	(0.57)	(0.85)	(3.22)	(0.86)	(1.25)	(1.88)
Canada	0.0018	0.0532	0.0708	–0.0090	0.0695	–0.9748
	(1.29)	(1.12)	(1.55)	(0.16)	(1.49)	(0.31)
US	0.0022	–0.0110	–0.0594	–0.0014	0.0507	1.6725
	(1.26)	(0.20)	(1.16)	(0.03)	(1.09)	(0.49)
France	0.0019	0.0617**	0.1187**	0.0162	0.1269***	–0.2980
	(1.23)	(2.13)	(2.30)	(0.58)	(3.43)	(0.11)
US	0.0012	0.0332	–0.0895***	–0.0764***	0.0775***	4.7758*
	(1.13)	(1.35)	(2.78)	(3.57)	(2.79)	(1.86)
Germany	0.0010	–0.0749**	0.1109***	0.0350	0.0473	3.1694
	(0.90)	(2.29)	(3.66)	(1.11)	(1.43)	(1.63)
US	–0.0001	–0.0098	–0.0862**	–0.0282	0.0477	8.2399**
	(0.06)	(0.37)	(2.41)	(0.97)	(1.57)	(2.49)
Italy	0.0008	0.0364	0.0362	0.0385	0.1073**	1.9313
	(0.48)	(1.10)	(0.78)	(1.30)	(2.04)	(1.00)
US	0.0008	–0.0149	–0.0726*	0.0018	0.0413	5.9882**
	(0.66)	(0.85)	(1.94)	(0.10)	(1.33)	(1.98)
Japan	0.0022**	–0.0316	0.0514	0.0520*	0.0020	0.5025
	(2.49)	–(1.17)	(1.51)	(1.65)	(0.06)	(0.35)
US	0.0015	–0.0189	–0.0726**	–0.0190	0.0441*	5.0418*
	(1.44)	–(0.76)	–(2.18)	–(0.80)	(1.86)	(1.73)
Netherlands	0.0019	–0.0345	0.2061***	0.0503	0.0548	–0.0930
	(1.51)	(0.89)	(4.16)	(1.46)	(1.33)	(0.03)
US	–0.0011	–0.0436	–0.0301	–0.0508	0.0854**	10.7641***
	(0.75)	(1.03)	(0.70)	(1.58)	(2.39)	(3.31)
Spain	0.0009	0.1486***	0.0735**	0.0545***	0.0219	1.5488
	(0.72)	(6.08)	(2.09)	(2.64)	(0.59)	(0.74)
US	0.0027*	0.0427**	–0.0656**	0.0136	0.0429**	–0.7142
	(1.92)	(2.04)	(2.32)	(0.64)	(2.09)	(0.19)
Switzerland	0.0015	0.0559	0.1639***	0.0479	0.0346	–0.4598
	(1.51)	(1.56)	(5.55)	(1.33)	(1.46)	(0.15)
US	–0.0024	0.0664	–0.0889***	–0.0276	0.0428	13.9951***
	(1.46)	(1.49)	(2.59)	(0.93)	(1.43)	(3.22)
Sweden	0.0043***	0.1131***	0.0885**	0.0557*	0.0042	–1.4177
	(3.45)	(3.73)	(2.06)	(1.90)	(0.12)	(0.69)
US	0.0016	0.0347	–0.1252***	–0.0004	0.0152	5.5182**
	(1.58)	(1.56)	(3.55)	(0.02)	(0.44)	(2.03)
UK	0.0042***	–0.0544**	0.1268***	0.1103***	0.0334	–5.4925***
	(3.90)	(1.99)	(3.55)	(4.19)	(1.24)	(2.60)
US	0.0022***	–0.0013	–0.0742**	–0.0107	0.0244	2.8588
	(2.82)	(0.05)	(2.27)	(0.46)	(0.92)	(1.49)

The numbers in parentheses are absolute *t*-statistics of the coefficient estimated.

The *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 3 Estimation results of the bivariate GARCH(1,1) model for the stock returns [variance equation, (9′)]

Country	C_{ij}		D_{ij}		G_{ij}	
Belgium	0.0006	0.0083*	0.7500***	0.7854***	–0.3106**	0.0394
	(0.22)	(1.82)	(19.74)	(7.99)	(2.18)	(0.42)
US		0.0003	–0.8210***	0.1921***	0.1441	0.3383***
		(0.01)	(16.66)	(4.17)	(1.31)	(6.83)
Canada	0.0004	0.0050	–1.2057***	–0.4341	–0.3915***	–0.1681
	(0.08)	(0.94)	(5.89)	(1.06)	(4.18)	(1.57)
US		0.0011	1.2981***	1.1654***	0.4367***	0.4365***
		(0.58)	(11.45)	(4.03)	(3.71)	(2.59)
France	0.0080***	0.0035**	0.7486***	–0.2603***	–0.2875***	0.0118
	(4.37)	(2.38)	(8.14)	(3.11)	(4.01)	(0.27)
US		0.0000	–1.1290***	–0.7567***	0.2489**	0.2990***
		(0.00)	(13.77)	(9.11)	(2.25)	(4.78)
Germany	0.0037***	–0.0057***	0.9879***	0.4423***	0.3045***	0.0520
	(3.04)	(3.14)	(25.75)	(2.92)	(8.61)	(1.14)
US		0.0000	–0.2541	–0.9252***	0.1004**	0.3702***
		(0.00)	(1.20)	(14.70)	(2.15)	(7.39)
Italy	0.0049**	–0.0047**	–0.9544***	–0.1010	0.3022***	–0.0130
	(2.11)	(2.25)	(61.58)	(0.80)	(7.26)	(0.42)
US		0.0000	0.4434	0.9366***	0.1462***	0.3395***
		(0.00)	(1.46)	(17.29)	(2.62)	(5.06)
Japan	0.0031**	0.0034	0.9378***	0.0044	0.3304***	–0.0061
	(2.07)	(0.80)	(36.58)	(0.44)	(6.00)	–(0.30)
US		0.0042**	–0.0502	0.9077***	0.1161	0.3230***
		(2.54)	(0.99)	(11.29)	(1.37)	(3.83)
Netherlands	–0.0015	0.0057**	1.1532***	0.6848*	–0.3141***	–0.1773**
	(0.64)	(2.56)	(26.69)	(1.82)	(7.74)	(2.01)
US		0.0000	–0.6315	–1.0761***	0.1163	0.3866***
		(0.00)	(1.55)	(20.56)	(0.59)	(2.70)
Spain	0.0056***	0.0002	0.8420***	0.5221***	–0.3788***	–0.1735***
	(6.51)	(0.36)	(20.45)	(6.97)	(8.55)	(4.50)
US		–0.0003	0.1784*	–0.9355***	–0.0995**	0.1128**
		(0.22)	(1.88)	(29.31)	(2.03)	(2.10)
Switzerland	0.0027*	–0.0034*	1.0117***	0.5076**	–0.4256***	–0.1524***
	(1.94)	(1.86)	(21.25)	(2.42)	(5.69)	(2.65)
US		0.0000	–0.4139**	–1.0534***	0.2607***	0.2978***
		(0.00)	(2.55)	(37.81)	(3.13)	(6.61)
Sweden	0.0060***	0.0022**	–0.9028***	0.0123	0.3520***	0.0142
	(5.12)	(2.02)	–(41.51)	(1.12)	(7.76)	(0.56)
US		0.0027**	0.0369	–0.9457***	0.1167**	0.2853***
		(2.21)	(1.31)	–(31.79)	(2.29)	(4.03)
UK	0.0068***	0.0042***	0.2039	0.9572***	–0.0596	–0.1453***
	(6.91)	(3.61)	(1.43)	(19.22)	(1.47)	(3.95)
US		0.0001	0.8067***	–0.3432***	0.3852***	0.4304***
		(0.39)	(9.43)	(3.08)	(5.65)	(7.25)

The numbers in parentheses are absolute *t*-statistics of the coefficient estimated.

*, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

The likelihood ratio test (LRT) for the null hypothesis H_0: $D_{ij} = 0$, $G_{ij} = 0$ is also performed. To save space, the results of the LRT are not reported. However, the null hypothesis is strongly rejected for each country. The *P*-values of the test are all very close to 0.

We also conduct the likelihood-ratio test that compares the GARCH model against the homoscedastic model (null) which restricts the matrix D and G to zero. The likelihood ratio statistics are all very large and the p-values are close to 0. The statistics from Table 2 and Table 3 show that the GARCH specification significantly improves our estimation of the bivariate stock-market return processes and is capable of capturing the time-varying volatility of the national stock markets. The findings of the time varying variance-covariance return structure have two important implications for asset pricing and portfolio management. Firstly, risk-averse investors would adjust their portfolios by reducing their commitments to assets whose volatility is predicted to rise or by using more sophisticated dynamic diversification approaches to hedge predicted volatility increases. Secondly, the information of cross-asset structure facilitates investors' asset-allocation strategy, allowing them to achieve optimal portfolio diversification across different international markets. Therefore, portfolio managers should track time-varying international correlation across markets and adjust their portfolios accordingly.

4.2 Foreign exchange risk premiums and time-varying equity market risks

Having derived the fitted series for the conditional variances of the residuals produced from the bivariate GARCH model, the relation between foreign exchange excess return and risk associated with the two exchange equity markets represented by equation (11) can be estimated. The full sample estimates are reported in Table 4. The coefficients of the conditional variances of the stock return for the two exchange countries are given by α_1 and α_2 (country i and the USA). The estimations are made by imposing and not imposing the constraint that $\alpha_1 = \alpha_2$. The former is labelled Model 2 and the latter Model 1. The statistics derived from both models produce very similar quantitative results. Consistent with our theoretical prediction, the expected volatilities of domestic and foreign equity markets have informational content in predicting foreign exchange profit, as seen by the significance tests. The exceptions are the markets of Belgium, France, and Japan.

We also conduct sub-period regressions to examine the relative importance of the risk factors of national equity markets. The evidence in Table 5 shows that the null hypothesis that the speculative profit in the foreign exchange markets is independent of the expected stock market risk is rejected, although the results may vary from period to period and country to country. It should be noted that the model fits the data relatively better for the sample periods from 1979 to 1983 and 1989 to 1993. For example, in the period from 1989 to 1993, the model can explain more than 30% of the variations for the forward-forecast errors for Germany and Spain and more than 20% for Belgium, Canada, France, Italy, Japan, and Sweden. In contrast, the average R-square for the entire sample period is only around 4%. The evidence in the current study confirms the hypothesis that excess returns in foreign exchange markets are correlated with relative expected risks in equity markets. The empirical results are informative for international asset pricing purposes.

Table 4 Estimations of the foreign exchange risk premium model (full sample)

Model 1: $s_{t+1} - f_t = \alpha_0 + \alpha_1 h_{11} + \alpha_2 h_{22} + \varepsilon_{t+1}$

Model 2: $s_{t+1} - f_t = \delta_0 + \delta_1 (h_{11} - h_{22}) + \varepsilon_{t+1}$

	Model 1				*Model 2*		
Countries	α_0	α_1	α_2	R^2	δ_0	δ_1	R^2
Belgium	–0.0063	5.3051	5.6269	0.0067	–0.0018	1.3608	0.0001
	(1.49)	(0.98)	(0.94)		(0.59)	(0.37)	
Canada	–0.0055***	–5.3883	10.8709***	0.0346	–0.0033***	–8.6290***	0.0205
	(3.42)	(1.38)	(3.69)		(3.65)	(2.98)	
France	–0.0012	–13.1011	15.7397	0.0227	0.0000	–13.5240	0.0223
	(0.20)	(1.21)	(1.45)		(0.01)	(1.34)	
Germany	–0.0094**	29.3053***	–14.3382*	0.1143	–0.0031	28.4823***	0.0934
	(2.42)	(3.21)	(1.70)		(1.06)	(3.34)	
Italy	–0.0110**	–6.4383*	21.0679***	0.0501	–0.0049	–6.3901*	0.0340
	(2.50)	(1.77)	(2.97)		(1.53)	(1.74)	
Japan	0.0007	3.5157	7.3119	0.0098	0.0054	2.7654	0.0023
	(0.16)	(1.00)	(0.76)		(1.62)	(0.76)	
Netherlands	–0.0038	–21.5660**	33.2604***	0.0429	0.0011	–24.5288**	0.0343
	(0.89)	(2.04)	(3.33)		(0.37)	(2.31)	
Spain	–0.0136**	22.0256***	–26.282	0.1604	–0.0152***	21.5566***	0.1600
	(2.16)	(5.17)	(1.41)		(4.82)	(5.77)	
Switzerland	–0.0046	24.1145*	–2.0909	0.0499	0.0041	23.2753*	0.0326
	(0.94)	(1.66)	(0.13)		(1.34)	(1.81)	
Sweden	–0.0059	11.5714***	–19.4360***	0.0442	–0.0090**	11.2773***	0.0386
	(1.20)	(2.87)	(2.67)		(2.02)	(2.80)	
United Kingdom	–0.0099**	15.5567**	2.5188	0.0232	–0.0032	23.4842**	0.0096
	(2.19)	(2.31)	(0.22)		(1.18)	(2.57)	

The numbers in parentheses are absolute t-statistics of the coefficient estimated.

The *t*-statistics here are heteroskedasticity consistent.

The *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 5 Estimations of the foreign exchange risk-premium model (sub-period)

Model 1: $s_{t+1} - f_t = \alpha_0 + \alpha_1 h_{11} + \alpha_2 h_{22} + \varepsilon_{t+1}$

Model 2: $s_{t+1} - f_t = \delta_0 + \delta_1 (h_{11} - h_{22}) + \varepsilon_{t+1}$

	Model 1				*Model 2*		
	α_0	α_1	α_2	R^2	δ_0	δ_1	R^2
Country: Belgium							
79:1–88:12	–0.0082	3.1556	6.2626	0.0052	–0.0039	–0.3554	0.0001
	(1.20)	(0.48)	(0.88)		(0.77)	(0.09)	
89:1–98:12	–0.0079	13.8665*	8.6814	0.0241	0.0003	6.7683	0.0017
	(1.29)	(1.77)	(0.88)		(0.09)	(1.18)	
79:1–83:12	–0.0010	–20.8778*	–31.4559*	0.1241	–0.0232***	–5.9068	0.0017
	(0.08)	(1.76)	(1.95)		(4.17)	(0.88)	
84:1–88:12	0.0052	9.4701**	11.4703**	0.0421	0.0153**	0.9809	0.0001
	(0.56)	(2.30)	(2.54)		(2.20)	(0.41)	
89:1–93:12	–0.0336***	46.3823***	58.2418***	0.2766	0.0025	13.0820	0.0046
	(3.93)	(4.61)	(4.42)		(0.49)	(1.08)	
94:1–98:12	0.0033	–1.0592	–12.0124	0.0120	–0.0017	3.0835	0.0005
	(0.35)	(0.12)	(0.92)		(0.38)	(1.19)	
Country: Canada							
79:1–88:12	–0.0056***	3.8616	4.4159	0.0473	–0.0018	–1.8159	0.0014
	(2.67)	(0.94)	(1.43)		(1.36)	(0.44)	
89:1–98:12	–0.0032	–39.8472***	33.4367***	0.1733	–0.0054***	–37.6536***	0.1694
	(1.36)	(6.25)	(3.87)		(4.70)	(5.75)	
79:1–83:12	–0.0016	9.7436**	–16.2084***	0.1307	–0.0045***	11.3585***	0.1000
	(0.70)	(2.38)	(4.12)		(4.74)	(2.93)	
84:1–88:12	–0.0052	7.9223	3.8317	0.0894	–0.0003	–3.9403	0.0045
	(1.62)	(1.30)	(1.14)		(0.13)	(1.05)	
89:1–93:12	–0.0060	–45.5086**	48.6892***	0.2432	–0.0050***	–48.2689***	0.2425
	(1.33)	(2.56)	(4.48)		(2.72)	(4.34)	
94:1–98:12	–0.0003	–20.7718**	3.7358	0.1580	–0.0063***	–23.4588***	0.0757
	(0.08)	(2.15)	(0.24)		(4.16)	(2.86)	
Country: France							
79:1–88:12	–0.0041	–14.5178	17.7311	0.0363	–0.0024	–15.1381	0.0357
	(0.50)	(1.33)	(1.55)		(0.48)	(1.52)	
89:1–98:12	–0.0110	13.8832	10.2424	0.0226	–0.0024	11.5394	0.0052
	(1.34)	(1.15)	(0.54)		(0.66)	(1.05)	
79:1–83:12	0.0227**	–29.8719***	–51.7841***	0.3640	–0.0167***	–23.3720***	0.1731
	(2.20)	(5.27)	(3.83)		(2.98)	(4.45)	
84:1–88:12	–0.0089	29.0131**	–3.1515	0.1049	0.0071	17.4765	0.0313
	(0.79)	(2.34)	(0.45)		(0.95)	(1.37)	
89:1–93:12	–0.0496***	58.8992***	60.3473	0.2715	–0.0041	28.7506	0.0163
	(3.83)	(3.35)	(1.61)		(0.60)	(1.26)	
94:1–98:12	0.0073	4.1499	–33.3604	0.0435	–0.0027	5.0119	0.0018
	(0.65)	(0.37)	(1.17)		(0.77)	(0.50)	

The numbers in parentheses are absolute t-statistics of the coefficient estimated.

The *t*-statistics here are heteroskedasticity consistent.

The *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 5 Estimations of the foreign exchange risk-premium model (sub-period) (continued)

Model 1: $s_{t+1} - f_t = \alpha_0 + \alpha_1 h_{11} + \alpha_2 h_{22} + \varepsilon_{t+1}$

Model 2: $s_{t+1} - f_t = \delta_0 + \delta_1 (h_{11} - h_{22}) + \varepsilon_{t+1}$

	Model 1				*Model 2*		
	α_0	α_1	α_2	R^2	δ_0	δ_1	R^2
Country: Germany							
79:1–88:12	–0.0123*	64.7219***	–41.0277***	0.2453	–0.0006	56.3367***	0.1858
	(1.96)	(3.75)	(3.05)		(0.15)	(3.24)	
89:1–98:12	–0.0040	18.9394**	–22.1230	0.0709	–0.0050	18.3276**	0.0706
	(0.68)	(2.52)	(1.29)		(1.50)	(2.46)	
79:1–83:12	–0.0024	7.9034	–25.9270	0.0296	–0.0091*	25.3302	0.0269
	(0.13)	(0.20)	(1.31)		(1.68)	(1.30)	
84:1–88:12	–0.0039	55.3319**	–35.1225*	0.1991	0.0080	47.4104*	0.1324
	(0.36)	(2.42)	(1.91)		(0.84)	(1.84)	
89:1–93:12	–0.0247***	40.3117***	7.8797	0.3355	–0.0098**	47.8095***	0.2765
	(2.84)	(4.68)	(0.28)		(2.14)	(7.53)	
94:1–98:12	0.0055	11.6793	–42.3779	0.0537	–0.0040	5.2988	0.0090
	(0.61)	(1.56)	(1.50)		(0.88)	(0.93)	
Country: Italy							
79:1–88:12	–0.0102*	–7.4168**	17.4933**	0.0740	–0.0051	–7.5507**	0.0664
	(1.71)	(2.15)	(2.37)		(1.14)	(2.20)	
89:1–98:12	–0.0276***	2.6223	51.3382**	0.0863	–0.0108**	5.7835	0.0078
	(3.39)	(0.42)	(2.15)		(2.19)	(0.90)	
79:1–83:12	–0.0054	–10.4389***	–16.4539	0.4004	–0.0179***	–10.4941***	0.3619
	(0.59)	(7.11)	(1.10)		(4.01)	(6.30)	
84:1–88:12	–0.0203**	28.0617***	–8.2581	0.2845	–0.0092	26.4246***	0.2235
	(2.24)	(4.05)	(1.24)		(1.26)	(3.96)	
89:1–93:12	–0.0576***	2.8166	133.1873**	0.2548	–0.0097	–0.7061	0.0001
	(3.50)	(0.27)	(2.44)		(1.26)	(0.05)	
94:1–98:12	–0.0085*	10.8556**	–21.6362	0.0668	–0.0113**	9.4080**	0.0576
	(1.79)	(2.23)	(1.15)		(2.43)	(2.49)	
Country: Japan							
79:1–88:12	0.0062	47.2628**	–25.7133	0.0744	0.0154**	36.4784*	0.0390
	(1.08)	(2.26)	(1.39)		(3.22)	(1.86)	
89:1–98:12	0.0097	11.9560***	–57.8646**	0.1194	–0.0056	10.4252***	0.0589
	(1.13)	(3.78)	(2.46)		(1.33)	(3.05)	
79:1–83:12	0.01180	–46.7022	–9.2533	0.0892	–0.0063	–6.0237	0.0011
	(1.26)	(1.22)	(0.28)		(0.91)	(0.17)	
84:1–88:12	0.0195**	21.9683	–1.7476	0.0595	0.0293***	10.0006	0.0035
	(2.25)	(0.97)	(0.10)		(4.64)	(0.49)	
89:1–93:12	0.0238***	14.5098***	–86.6246***	0.2688	0.0009	11.1553***	0.1307
	(2.68)	(5.00)	(3.25)		(0.18)	(2.89)	
94:1–98:12	–0.0001	6.1972	–34.9387	0.0376	–0.0105	6.2219	0.0100
	(0.01)	(0.65)	(1.09)		(1.37)	(0.63)	

The numbers in parentheses are absolute t-statistics of the coefficient estimated.

The *t*-statistics here are heteroskedasticity consistent.

The *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 5 Estimations of the foreign exchange risk–premium model (sub–period) (continued)

Model 1: $s_{t+1} - f_t = \alpha_0 + \alpha_1 h_{11} + \alpha_2 h_{22} + \varepsilon_{t+1}$

Model 2: $s_{t+1} - f_t = \delta_0 + \delta_1 (h_{11} - h_{22}) + \varepsilon_{t+1}$

	Model 1				*Model 2*		
	α_0	α_1	α_2	R^2	δ_0	δ_1	R^2
Country: Netherlands							
80:1–88:12	–0.0022	–29.4785	37.9367***	0.0528	0.0021	–35.5823**	0.0487
	(0.25)	(1.59)	(2.74)		(0.40)	(2.49)	
89:1–98:12	–0.0041	–16.8843	29.4729	0.0272	0.0003	–15.123	0.0222
	(0.58)	(1.29)	(1.23)		(0.11)	(1.11)	
80:1–83:12	–0.0214	–8.8616	13.231	0.0085	–0.0193***	–11.3267	0.0080
	(1.09)	(0.39)	(0.63)		(3.88)	(0.86)	
84:1–88:12	0.0176*	–44.9303**	47.4802**	0.0999	0.0190***	–46.9506**	0.0993
	(1.69)	(2.01)	(2.49)		(2.71)	(2.50)	
89:1–93:12	–0.0329**	106.1207***	0.1739	0.0021	–5.5924	0.0004	
		16.0453					
	(2.57)	(3.15)	(0.38)		(0.39)	(0.16)	
94:1–98:12	0.0053	–9.4301	–8.9096	0.0447	–0.0009	–13.8760	0.0323
	(0.52)	(0.62)	(0.30)		(0.21)	(0.91)	
Country: Spain							
79:1–88:12	–0.0090	27.2249***	–43.7454	0.2330	–0.0170***	24.9880***	0.2282
	(0.77)	(4.05)	(1.57)		(3.73)	(4.25)	
89:1–98:12	–0.0288	6.6929	58.0805	0.0837	–0.0114***	13.5998***	0.0559
	(2.54)	(1.25)	(1.54)		(2.76)	(2.69)	
79:1–83:12	0.0551***	37.4115	–213.4186***	0.2924	–0.0292***	46.1677	0.0821
	(2.60)	(1.05)	(4.20)		(3.77)	(1.13)	
84:1–88:12	–0.0103	11.6494***	12.7709	0.2693	0.0014	15.2382***	0.2397
	(0.98)	(2.78)	(0.75)		(0.27)	(3.99)	
89:1–93:12	–0.0920***	5.7497	242.3792***	0.3494	–0.0133**	24.7757***	0.1228
	(4.06)	(0.85)	(3.64)		(2.13)	(4.11)	
94:1–98:12	0.0146	21.4141***	–135.3342**	0.0778	–0.0089*	3.9252	0.0084
	(1.04)	(2.82)	(2.08)		(1.81)	(0.87)	
Country: Switzerland							
79:1–88:12	0.0019	100.9187***	–65.1227***	0.2337	0.0169***	89.9503***	0.1776
	(0.27)	(5.25)	(3.32)		(3.69)	(4.55)	
89:1–98:12	0.0044	10.9626	–23.4176	0.0103	0.0002	9.1026	0.0088
	(0.38)	(1.47)	(0.59)		(0.07)	(1.57)	
79:1–83:12	0.0107	36.9551	–61.5091*	0.0680	0.0033	55.6879*	0.0522
	(0.82)	(1.32)	(1.85)		(0.41)	(1.73)	
84:1–88:12	0.0052	91.976***	–51.8223**	0.2450	0.0236***	80.3893***	0.1578
	(0.52)	(3.70)	(2.52)		(3.75)	(3.18)	
89:1–93:12	–0.0412**	72.6123**	62.5722	0.1767	0.0029	66.1487	0.0463
	(2.16)	(2.22)	(0.90)		(0.48)	(1.27)	
94:1–98:12	0.0377**	24.2398***	–137.9159**	0.1533	0.0009	5.2454	0.0058
	(2.31)	(2.76)	(2.44)		(0.18)	(1.13)	

The numbers in parentheses are absolute t-statistics of the coefficient estimated.

The *t*-statistics here are heteroskedasticity consistent.

The *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 5 Estimations of the foreign exchange risk–premium model (sub–period) (continued)

Model 1: $s_{t+1} - f_t = \alpha_0 + \alpha_1 h_{11} + \alpha_2 h_{22} + \varepsilon_{t+1}$

Model 2: $s_{t+1} - f_t = \delta_0 + \delta_1 (h_{11} - h_{22}) + \varepsilon_{t+1}$

	Model 1				*Model 2*		
	α_0	α_1	α_2	R^2	δ_0	δ_1	R^2
Country: Sweden							
82:9–88:12	–0.0016	19.9273***	–30.0799***	0.0991	–0.0067	19.8479***	0.0846
	(0.23)	(3.23)	(3.82)		(1.13)	(3.09)	
89:1–98:12	–0.0038	11.9410	–43.5901	0.0446	–0.0118*	8.3806*	0.0264
	(0.47)	(1.57)	(1.09)		(1.79)	(1.91)	
82:9–83:12	–0.0354	6.3641	–35.5336	0.0518	–0.0497***	17.6967	0.0355
	(1.37)	(0.27)	(1.33)		(8.02)	(1.38)	
84:1–88:12	0.0129*	13.4065***	–25.9673***	0.1247	0.0065	13.1692**	0.0770
	(2.02)	(2.75)	(4.97)		(1.24)	(2.53)	
89:1–93:12	0.0422***	–0.0772	–221.8384***	0.2644	–0.0164*	11.1065	0.0176
	(4.05)	(0.01)	(5.01)		(1.94)	(0.99)	
94:1–98:12	0.0081	3.1125	–8.7065	0.0246	0.0059	2.2949	0.0226
	(0.46)	(0.67)	(0.22)		(0.92)	(1.10)	
Country: United Kingdom							
79:1–88:12	–0.0120	9.5521	11.0371	0.0251	–0.0028	18.4593	0.0073
	(1.57)	(1.37)	(0.93)		(0.65)	(1.64)	
89:1–98:12	–0.0109	38.6429**	–16.9037	0.0317	–0.0043	48.3991**	0.0209
	(1.35)	(2.27)	(0.88)		(1.37)	(2.05)	
79:1–83:12	–0.0059	–17.9062	8.3577	0.0069	–0.0103*	–20.444	0.0047
	(0.45)	(0.95)	(0.56)		(1.73)	(0.86)	
84:1–88:12	–0.0082	10.2047***	21.4163***	0.0864	0.0056	25.5832***	0.0223
	(0.92)	(4.40)	(2.94)		(0.93)	(3.55)	
89:1–93:12	–0.0330	42.5507	25.4013	0.0838	–0.0113	74.3235	0.0263
	(1.76)	(1.08)	(0.81)		(2.22)	(1.37)	
94:1–98:12	0.0041	–1.4795	2.9414	0.0003	0.0045***	–0.7301	0.0001
	(1.27)	(0.22)	(0.37)		(2.48)	(0.08)	

The numbers in parentheses are absolute t-statistics of the coefficient estimated.

The *t*-statistics here are heteroskedasticity consistent.

The *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

5 Summary and concluding remarks

In this paper, we test the potential existence of time-varying risk premiums in the forward foreign exchange market by employing a wide range of data in foreign exchange and stock markets. Utilising the VAR process with bivariate GARCH-in-mean innovations, we generate risk variables as measured by conditional variances in stock markets. By hypothesising that risk premiums in foreign-exchange markets are independent of expected risks in domestic and foreign stock markets, we find evidence to reject the null hypothesis, confirming the time-varying risk-premium argument. An important message emerging from our study is that the relative stock-return volatility effectively summarises relative market risk, which is compensated by the speculative profit from the foreign exchange market.

In addition, we derive two more empirical regularities that can be helpful in advising investors in managing their international portfolios. Firstly, in addition to the AR(1) term, national stock returns are seen to be explained significantly by US stock returns. This suggests that national stock returns can be predicted by using both domestic and US stock return news. Secondly, the coefficients on a vector GARCH model are highly significant, suggesting that the volatility evolution of stock returns displays not only a clustering phenomenon, but also a significant spillover effect. Given the fact that the correlation structure across markets is time varying, investors and portfolio managers should continually assess this information and rebalance their portfolios over time to achieve optimal diversification.

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24 Chiang [12] tests the international capital asset pricing model for four currencies over the period of March 1973 to January 1987, which is a period in part characterised by exchange controls. Morley and Pentecost [13], including all the G-7 countries in their study, test the model over the period of January 1982 to January 1994, when many of the capital controls in the 1970s had been relaxed or abolished. In this study, the sample period covers January 1979 to December 1998, which highlights the recent 20-year floating exchange system. The end date is dictated by the availability of data; note that the Euro becomes a single currency for the EMU countries after January 1999.

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34 In those models the expected nominal speculative profit for a particular currency is related to the world index or to the risk premium in the US equity market alone.

35 Many empirical studies document supportive evidence for the relationship between expected equity premiums and ex ante stock return variances (e.g., French *et al.* [22]).

36 Although we focus on the risk from equity markets, other risk factors, such as political risk or purchasing power risk, may also be reflected in the variations of equity risk.

37 The stock-market indices for the Netherlands and Sweden are from 1980:1:4 and 1982:9:3, respectively.

38 Eun and Shim [39] find that innovations in the US market are rapidly transmitted to the rest of the world. Schwert and Seguin [40] have documented that the variance of aggregate stock returns changes over time. The investigation of conditional volatility of the US stock market has been extensively undertaken. The issue has been tested in other stock markets, specifically the application of (G)ARCH models has been investigated by de Jong *et al.* [41] (Netherlands), Tse [42] (Japan), Tay and Tse [43] (Singapore), Poon and Taylor [44] (UK). Based on the summary statistics, the return series are predictable and exhibit conditional heteroskedasticity.

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