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Do foreign exchange risk premiums relate to the volatility in the foreign exchange and equity markets?

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Empirical tests are performed to examine whether foreign exchange excess returns for the British pound, Canadian dollar, Deutsche mark, and Japanese yen are related to volatility in the currency market and volatility in the stock markets. Our results indicate that volatility (measured by standard deviation and variance) from currency markets is significant in explaining the excess returns, suggesting that the excess returns are indeed reward for risk-taking. In addition, shocks in equity markets are found to have a significant impact on currency risk premium as well. In some cases, we find nonlinearity in the risk premium. Finally, our results emerged from Glosten, Jagannathan, Runkle's model (*Journal of Finance*, **48**(5), 1993) suggest that risk premiums for each currency tend to respond to positive and negative shocks differently.

I. INTRODUCTION

A considerable amount of empirical work has been devoted to analysing the relationship between excess return in the foreign exchange market and risk factors (Hodrick, 1987; Bekaert and Hodrick, 1992). This area of research is particularly meaningful in helping us search for the answer to whether the foreign exchange excess return is indeed a risk premium and what are the risk factors that drive the risk premium. Frankel (1993, p. 228) states that 'the existence of deviations of exchange rate changes from the forward discount, even if serially correlated, does not itself constitute evidence for a risk premium.'[1] Thus research on foreign exchange risk premium calls for relating excess return to various risk measures directly.

In order to explain the excess return of the forward exchange contract, various asset pricing models have been advanced in the recent literature. One approach is derived from the consumption-based model that maximizes an agent's utility function. Following the Lucas (1982) asset pricing framework, it can be shown that the excess return on the foward exchange market is dependent on the conditional covariance of the intertemporal marginal rates of substitution and the probability distribution function of macroeconomic and financial variables. Research along this line includes Hodrick and Srivastava (1984), Domowitz and Hakkio (1985), Giovannini and Jorion (1987), Mark (1988), Cumby (1988), and Backus *et al.* (1990).

The second approach is to employ the Capital Asset Pricing Model (CAPM). The CAPM approach measures the covariance between the forward excess return and the 'market' excess returns. In particular, Roll and Solnik (1977) estimate the covariance between the 'extraordinary' exchange return and the 'index' of the exchange return; Robichek and Eaker (1978) relate the exchange return to the systematic risk; and Chiang (1991) links the forward excess return to the relative ex ante risk in the equity markets.

The third approach is to utilize an equilibrium version of the Arbitrage Pricing Theory (APT). This postulates that the excess returns on forward exchange markets are corre-

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[1] Hansen and Hodrick (1980) use latent variable approach to study foreign exchange excess return. They find that excess returns are serially correlated.

lated to the excess returns on the benchmark portfolio and the latter can be specified as a linear combination of the returns on factor-mimicking portfolios. By further relating the returns of factor-mimicking portfolios to various risk measures, hypothesis about relationship between risk and excess return can be evaluated. Along this line of investigation, Korajczyk and Viallet (1990) provide evidence to support the existence of risk premiums.[2]

Built on previous empirical evidence, this paper is another attempt to examine the relationship between excess foreign exchange returns and risk factors. In particular, our study is motivated by two recent empirical developments in the asset markets. First, risk-averse behaviour implies that the expected excess returns on assets are tied closely to the expected risk premiums, and the latter are thought to covary with the conditional volatility. The findings by Merton (1980), Pindyck (1984), and French *et al.* (1987) consistently support a positive relation between US stock market returns and the expected volatility of stock returns. Second, the correlations between US stock market returns and returns in the foreign exchange market are significant. The risk premiums in the stock market and the forward foreign exchange market follow very similar empirical characteristics; their condition distributions are both correlated with nominal interest rates (Giovannini and Jorion, 1987; Schwert, 1989). In addition to that, a strand of research has identified a causal and feedback relationship between the equity market and the currency market. Chiang (1991) finds that equity risk premiums are useful in explaining the variation in currency risk premium in a multivariate transfer function framework. Therefore, it is clearly suggested that the stock market volatility can lead to a change in the perceived risk of the foreign exchange market. Moreover, since all exchange rates are relative prices of two assets (currencies), their movements should be affected by voltatility arising from both domestic and foreign equity markets.[3] Taylor (1988) proposes a dynamic multiple-indicator multiple cause (DYMIMIC) model in which the risk premium is modelled as a latent variable. It is further assumed that the latent variable is a function of its own lagged value and respective stock market volatility. His findings suggest that currency risk premium is significantly influenced by relative asset yield volatility (stock market volatility).

On the basis of these empirical regularities, in this paper we perform a direct test relating the excess returns of the forward exchange market to the conditional volatility revealed in the foreign exchange market and in the stock markets. Different from previous research where only the currency market volatility (Domowitz and Hakkio, 1985; Lyons, 1988) is considered, we also include volatility from the relevant stock markets. Recent evidence on volatility spillover across various asset markets and market integration warrants that our approach is a necessary extension of previous findings. In addition to measures volatility through the conventional moving average method (Merton, 1980; Pindyck, 1984) and GARCH model, this paper also applies a variation of the GARCH model which would allow us to examine the potentially different impact of positive shocks and negative shocks in the market.

The paper is organized as follows. Section II presents a model that relates the foreign exchange excess return to the expected and unexpected volatility in the foreign exchange and stock markets. Section III describes the data set and measures of volatility. Section IV reports empirical results on relationship between currency excess return and volatility generated through time series models. Section V further extends the study by employing several models in the GARCH family to characterize the conditional mean and volatility simultaneously. Section VI contains a conclusion.

II. THE MODEL

A conventional analysis of the foreign exchange excess return is to set up an orthogonality test by examining the significance between the expected excess foreign exchange return and a vector of macroeconomic variables or conditional variances, x. Specifically, we write:

$$E(s_{t+1} - f_t|\Omega_t) = x\beta \tag{1}$$

where s and f are the spot exchange rate and the forward rate in natural logarithms respectively. $E(\cdot|\Omega_t)$ is an expectation operator conditional on information set Ω_t available at time t. $E(s_{t+1} - f_t|\Omega_t)$ is the speculative profit (excess return) or error from the forward exchange market. This notion also implies the Fisher position if covered interest rate parity holds. β has dimension of $kx1$ and x is a $1xk$ row vector. In previous research the candidates for x include news (Frenkel, 1981), latent variables (Hansen and Hodrick, 1980, Giovannini and Jorion, 1987; Cumby, 1990), real interest rate differential (Korajczyk, 1985), conditional variances (Domowitz and Hakkio, 1985), and the equity risk premium (Robichek and Eaker, 1978; Korajczyk and Viallet, 1990; and Chiang, 1991). Since our interest is confined to the risk factors, Equation 1 is conveniently written as

[2] One other interesting approach employs signal extraction techniques to empirically model the time series properties of the risk premium. Wolff (1987) applies a Kalman filter model to the forward discount/premia to extract the currency premia. He finds that the extracted premia display a certain degree of persistence over time and can account for more than half of the variations in forward discount/premia.

[3] In an integrated world equity market, currency excess return should be related to volatility of world equity market only.

$$E(s_{t+1} - f_t|\Omega_t) = \alpha_0 + \sum_j \alpha_{j,t} E(\lambda_{j,t+1}) \quad (2)$$

Equation 2 implies that the excess return is a linear combination of a vector of expected risk premiums, $E(\lambda_{j,t+1})$ which in turn correspond to measures of expected volatility of asset returns. That is,

$$E(s_{t+1} - f_t|\Omega_t) = \lambda_0 + \sum_j \lambda_{j,t} E(\sigma^p_{j,t+1}|\Omega_t) \quad (3)$$

where volatility is measured by $\sigma^p_{j,t+1}$, which denotes standard deviation $(p = 1)$ or variance $(p = 2)$. Since econometricians are constrained by the availability of data and by information costs, a smaller information set ω_t is usually used in empirical estimations. In our model specification, the expected values of $\sigma^p_{s,t}$, $\sigma^p_{m,t}$, $\sigma^p_{m^*,t}$, where s stands for foreign exchange market, m and m^* denote domestic and foreign stock markets, can be generated from information set ω_t. Equation 3 is similar to Merton (1980) and Pindyck (1984) models in estimating the relation between the market risk premium and volatility. However, the realized variance was used in their estimations. Since the right-hand side variables, the expected volatility, are conditional state variables, and are not correlated with the unexpected components of volatility, both expected and unexpected components can be simultaneously included in the model. This leads us to specify:

$$\begin{aligned} s_{t+1} - f_t &= \beta_0 + \beta_1 E(\sigma^p_{s,t+1}) + \beta_2 U(\sigma^p_{s,t,+1}) \\ &\quad + \beta_3 E(\sigma^p_{m,t+1}) + \beta_4 U(\sigma^p_{m,t+1}) \\ &\quad + \beta_5 E(\sigma^p_{m^*,t+1}) + \beta_6 U(\sigma^p_{m^*,t+1}) + \varepsilon_{t+1} \end{aligned} \quad (4)$$

where β_j, $j = 1, 2, \ldots, 6$ are constant coefficients, $E(\cdot)$ and $U(\cdot)$ are the expected and unexpected components of the variable under consideration respectively, and ε_{t+1} is a disturbance term. Equation 4 enables us to test the hypothesis that the excess returns in foreign exchange markets are related to the expected and unexpected volatility in the foreign exchange markets and in the stock markets. A rejection of the null hypothesis $\beta_j = 0$ in the significance test implies that the exchange excess return is indeed associated with the conditional volatility, thus suggesting the existence of risk premium.

In comparison with previous studies of exchange risk premiums, the model specified in Equation 4 has several special features that allow us to test the following hypotheses explicitly. First, Equation 4 provides a direct test in relating the forecast error to measurements of risk, specifically, the expected and unexpected volatility. The results emerged would provide further evidence on whether the forecasting error can be attributed to time varying risk premium.[4] Second, volatility from currency market as well as those from the relevant stock markets are incorporated into the model specification. The inclusion of asset volatility from stock markets allows us to explore the information reflected in other asset markets.[5] The results of the test are bound to offer insights on the factors involving multi-asset analysis. Third, in empirical specification, previous research proposes (French *et al.*, 1987) that either the conditional forecasts of standard deviation or variance of returns can be used to measure the volatility. However, similar to Fama and MacBeth's (1973) test of equity market asset pricing, Equation 4 states that both the standard deviation and the variance can be considered as independent arguments. In such a treatment, the test relation is nonlinear. The empirical result will provide us with a better understanding with respect to the appropriate model specification.

III. THE DATA AND MEASURE OF VOLATILITY

In order to measure the excess return in the foreign exchange market, which is $s_{t+1} - f_t$, end of the month spot rates and forward rates were taken from the *Weekly Review* of the Harris Bank. Both spot and forward rates are quoted as dollar prices of foreign currencies.

Daily exchange rates (the US dollar price of foreign currencies) and daily observations on stock returns for US (S&P 500), UK (Total Market Index), Canada (Toronto Composite), Japan (Nikkei Index), and West Germany (Total Market Index) were obtained from Datastream. High frequency daily data were used to generate monthly variances of stock market indices and exchange rates for the period from June 1973 to December 1990.[6] Following the procedure suggested by French *et al.* (1987), the monthly variance is constructed by the sum of squared daily returns plus twice the sum of products of the adjacent returns. Specifically,

$$\sigma_t^2 = \sum_{i=1}^{Nt} r_{i,t}^2 + 2\sum_{i=1}^{Nt-1} r_{i,t} r_{i,t-1} \quad (5)$$

where σ_t^2 is the actual monthly variance of the independent variable, $r_{i,t}$ is the return on the stock market or the log-difference of the spot exchange rate, and N_t is the number of days in month t. The second term in Equation 5 is included to account for the first-order autocorrelation of

[4] Recent developments on international asset pricing centres on whether the forward forecast error is a risk premium, an expectational error, or a statistical artefact. Unless significant relationship is found between the forecast error and risk measure, even serial correlations in the forecast error cannot be considered evidence for risk premium.
[5] Lyons (1988) uses volatility derived from currency option market and finds evidence in support of existence of risk premium.
[6] For the Japanese yen, the forward rate series begins from January 1976.

returns caused by nonsynchronous trading (Scholes and Williams, 1977). By the same token, the measure of the standard deviation is constructed by taking the squared root of Equation 5. That is,

$$\sigma_t = \left(\sum_{i=1}^{Nt} r_{i,t}^2 + 2\sum_{i=1}^{Nt-1} r_{i,t}r_{i,t-1}\right)^{1/2} \quad (5')$$

This estimator is superior to the one generated from the rolling smoothing method used in Merton (1980) due to the fact that the overlapping data problem can be eliminated.

Table 1 presents some summary statistics for the risk premiums in the Canadian, Japanese, UK, and West German markets. Consistent with previous findings, it can be shown that the magnitude of the foreign exchange excess return is relatively small and none of them is statistically significant. For the Canadian dollar, German mark and Japanese yen, the unconditional means are negative, indicating that the forward markets can best be characterized by net excess demand. Therefore, risk premiums are rewarded for taking short positions. The exception is for the British pound, where speculators are compensated for their purchases of pound to equilibrate the supply and demand. Summary statistics for monthly variances and standard deviations generated from Equations 5 and 5′ are also reported in Table 1. For currency markets, the volatility of the spot rates in Japan, the UK, and West Germany is of a very similar magnitude while the Canadian market appears to have the highest volatility. In the stock markets, the variances for Japan and for the US are of a similar degree, while those for Canada, the UK, and West Germany are lower and of similar magnitude.

The estimations of Equation 4 are obtained in a two-stage approach. First, we generate the expected and unexpected volatility by fitting the estimated volatility for each series into ARIMA models. Second, the predicted and unpredicted values of the volatility are then used to replace the expected and unexpected values in the estimating equation. The ARIMA model can be represented by the following process:

$$\sigma_t^p = \Phi(L)^{-1}\theta(L)e_t \quad (6)$$

where e_t is white noise, $\Phi(L)$ and $\theta(L)$ are polynomials in L of orders p and q. By construction, the predicted value of the monthly volatility, $E(\sigma_t^p)$, derived from the ARIMA process is considered to be the expected volatility conditional on information at time t. The difference between σ_t^p and $E(\sigma_t^p)$ is the unexpected volatility of respective asset returns $U(\sigma_t^p)$. These values then will be used in the next stage for the estimation of Equation 4. We do not report the ARIMA model fitted for each currency here, however, we do observe time dependency in most of the cases, that is, past volatility helps in explaining the future volatility. Model specification does vary among currencies.

IV. EMPIRICAL EVIDENCE

We begin our empirical tests by applying the ordinary least squares method to Equation 4. The estimations proceed as follows. First, we estimate the impacts of the volatility arising from the different markets on forward exchange excess returns separately. Second, we examine the test relation by incorporating all the volatility from different mar-

Table 1. *Time series properties of foreign exchange excess return and volatility in the foreign exchange and stock markets*

			Autocorrelations											
Country	Mean	Std. Dev.	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	ρ_8	ρ_9	ρ_{10}	ρ_{11}	ρ_{12}
Foreign exchange excess return														
Canada	−0.37E-03	0.012	0.12	0.01	0.12	0.07	0.17	0.00	0.00	0.22	0.08	0.17	0.17	−0.04
Japan	−0.47E-03	0.036	0.08	0.12	0.13	0.06	0.13	−0.10	0.10	0.01	0.06	−0.02	0.12	0.09
UK	0.18E-02	0.034	0.08	0.05	−0.01	0.04	0.09	−0.07	0.02	0.05	0.04	−0.02	0.12	−0.01
WG	−0.20E-02	0.035	0.03	0.19	0.07	0.03	0.13	−0.03	0.13	0.03	0.11	0.08	0.16	0.02
Estimated actual variance of exchange rate return														
Canada	0.16E-03	0.21E-04	0.26	0.06	0.00	−0.02	−0.09	−0.12	−0.08	−0.14	−0.07	0.00	0.14	0.13
Japan	0.89E-03	0.84E-04	0.23	0.10	0.10	0.15	0.18	0.21	0.16	0.13	−0.02	−0.03	0.03	0.08
UK	0.10E-02	0.97E-04	0.38	0.20	0.10	0.22	0.33	0.32	0.10	0.01	−0.04	0.10	0.10	0.06
WG	0.95E-03	0.98E-04	0.38	0.08	−0.03	−0.03	0.04	0.26	0.18	0.02	0.00	0.12	0.11	0.15
Estimated actual variance of stock return														
Canada	0.13E-02	0.13E-03	0.28	0.35	0.14	0.21	0.33	0.16	0.20	0.10	0.16	0.06	0.12	0.07
Japan	0.81E-03	0.80E-04	0.44	0.27	0.26	0.14	0.20	0.19	0.17	0.02	0.01	0.03	0.00	0.00
UK	0.18E-02	0.11E-03	0.46	0.32	0.14	0.15	0.17	0.16	0.07	0.07	0.00	0.11	0.11	0.11
US	0.15E-02	0.89E-04	0.41	0.45	0.29	0.19	0.23	0.18	0.14	0.09	0.14	0.08	0.11	0.10
WG	0.12E-02	0.12E-03	0.60	0.55	0.52	0.46	0.54	0.55	0.45	0.36	0.21	0.23	0.20	0.29

Note: ρ_i $(i = 1, \ldots, 12)$ is autocorrelation at lag *i*.

kets into a unified model. In order to investigate whether results are sensitive to different measures of the volatility (standard deviation versus variance), both measures are employed in our estimations.

Panel A of Table 2 presents the estimated results from regressing exchange excess returns on the expected and unexpected spot rate volatility. The testing results show no supportive evidence for using the standard deviation as a volatility measure. However, the null hypothesis can be rejected in the cases of the Canadian dollar and the Japanese yen when variance is used to measure the volatility. For the British pound, and German mark, the data indicate that the volatility in the currency market *per se*, both expected and unexpectd, provides no significant effect on the expected foreign exchange risk premiums.

Looking into the information revealed in the relevant equity markets, we test the model by fitting exchange excess returns on the expected and unexpected stock market volatility. The results are reported in Panel B of Table 2. For all the countries the model under investigation gains some support. In particular, we found that the expected exchange excess returns for Canada, Japan, and West Germany are correlated with the predicted stock volatility in the US market. However, the expected exchange excess returns in the UK are correlated with its own stock volatility. More interestingly, a nonlinear relation is found in markets of Japan, the UK, and West Germany. In these markets, the exchange risk premiums are associated with the standard deviation and the variance of the stock returns. Comparing the data reported in Panel A and Panel B, we find that volatility in equity markets tends to be more informative than currency market volatility itself in explaining the forward excess return.

Finally, Equation 4 is estimated by incorporating all the risk measures in the foreign exchange markets and stock markets and the results are reported in Table 3. Consistent with the evidence reported in Table 2, we once again reject the null hypothesis that the exchange excess return is uncorrelated to an *ex ante* measure of the volatility. The results emerging from the test equation indicate that *ex ante* volatility in the currency market is significant for the Canadian dollar and the Japanese yen, while measures of the US stock market volatility are significant for the German mark and the Canadian dollar. The evidence continually indicates that the exchange excess return in the UK is highly correlated with the UK's stock market volatility. As we reported earlier, the relation between exchange excess returns and the measures of *ex ante* volatility appear to be nonlinear. This new evidence provides us with a better understanding of the behaviour of the exchange risk premiums.

Table 2. *Regression results on foreign exchange excess return and asset market volatility*

Panel A. Standard deviations and variances of foreign exchange market

$$s_{t+1} - f_t = \beta_0 + \beta_1 E(\sigma_{s,t+1}) + \beta_2 U(\sigma_{s,t+1}) + \beta_3 E(\sigma^2_{s,t+1}) + \beta_4 U(\sigma^2_{s,t+1}) + \varepsilon_{t+1}$$

Country	β_0	β_1	β_2	β_3	β_4	R^2	DW
Canada	−0.001	−0.889	−0.160	93.490*	−69.916*	0.087	1.803
73:6–90:12	(0.006)	(0.680)	(0.440)	(37.212)	(21.262)		
Japan	0.229	−13.760	−0.260	210.319	9.088*	0.051	1.786
76:1–90:12	(0.189)	(11.820)	(0.354)	(183.881)	(3.914)		
UK	0.003	−0.559	−0.169	17.216	1.293	0.012	1.952
73:6–90:12	(0.063)	(3.506)	(0.359)	(48.845)	(0.800)		
WG	0.019	−1.353	0.162	18.417	1.060	0.010	2.134
73:6–90:12	(0.023)	(1.525)	(0.369)	(25.376)	(3.618)		

Panel B. Standard deviations and variances from equity markets

$$s_{t+1} - f_t = \beta_0 + \beta_1 E(\sigma_{m,t+1}) + \beta_2 E(\sigma_{m*,t+1}) + \beta_3 U(\sigma_{m,t+1}) + \beta_4 U(\sigma_{m*,t+1}) + \beta_5 E(\sigma^2_{m,t+1}) + \beta_6 E(\sigma^2_{m*,t+1}) + \beta_7 U(\sigma^2_{m,t+1}) + \beta_8 U(\sigma^2_{m*,t+1})) + \varepsilon_{t+1}$$

Country	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	R^2	DW
Canada	−0.035	1.837	−0.527	0.080	−0.103	−18.268*	7.578	3.316	−2.673*	0.121	1.805
73:6–90:12	(0.037)	(1.385)	(1.403)	(0.119)	(0.113)	(15.208)	(15.988)	(1.481)	(1.180)		
Japan	0.139	−6.621**	0.332	−0.080	−0.203	68.524**	−1.944	3.050	−2.230	0.033	1.720
76:1–90:12	(0.118)	(3.897)	(4.253)	(0.343)	(0.475)	(43.042)	(59.845)	(3.689)	(5.338)		
UK	0.225	−1.944	−7.294*	0.281	−0.025	12.113	73.717*	−4.334	−2.341	0.085	1.805
73:6–90:12	(0.124)	(3.796)	(3.505)	(0.330)	(0.280)	(42.063)	(34.042)	(3.879)	(2.860)		
WG	0.224	−8.729*	−1.709	−0.166	0.082	88.065*	31.333	−1.052	0.447	0.147	2.227
73:6–90:12	(0.085)	(3.669)	(1.350)	(0.321)	(0.324)	(40.385)	(15.899)	(3.424)	(3.452)		

Note: * and ** denote statistical significance levels at 5% and 10% respectively. Standard errors are in parentheses.

Table 3. *Test nonlinearity of foreign exchange excess return with respect to volatility in the foreign exchange and equity markets* $s_{t+1}-f_t=\beta_0+\beta_1 E(\sigma_{s,t+1})+\beta_2 U(\sigma_{s,t+1})+\beta_3 E(\sigma^2_{s,t+1})+\beta_4 U(\sigma^2_{s,t+1})+\beta_5 E(\sigma_{m,t+1})+\beta_6 E(\sigma_{m*,t+1})+\beta_7 U(\sigma_{m,t+1})+\beta_8 U(\sigma_{m*,t+1})$ $+\beta_9 E(\sigma^2_{m,t+1})+\beta_{10} E(\sigma^2_{m*,t+1})+\beta_{11} U(\sigma^2_{m,t+1})+\beta_{12} U(\sigma^2_{m*,t+1})+\varepsilon_{t+1}$

Country	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}	β_{12}	R^2	DW
Canada	−0.038	−9.589	−0.355	75.567*	−62.012*	2.168	−0.818	0.043	−0.088	−21.172	9.826	3.180*	−2.371*	0.185	1.779
73:6–90:12	(0.037)	(0.683)	(0.439)	(36.856)	(21.241)	(1.367)	(1.381)	(0.117)	(0.111)	(14.815)	(15.669)	(1.458)	(1.172)		
Japan	0.286	−11.340	−0.323	179.421*	10.385*	−5.363	1.359	0.051	−0.270	54.923	−12.241	0.998	−3.311	0.087	1.721
76:1–90:12	(0.217)	(13.069)	(0.370)	(201.302)	(4.281)	(3.980)	(4.249)	(0.343)	(0.479)	(43.556)	(59.573)	(3.762)	(5.387)		
UK	0.212	1.813	−0.300	−17.910	2.240	−3.478	−6.597**	0.262	−0.012	27.808	66.900*	−4.293	−2.741	0.094	2.109
73:6–90:12	(0.139)	(3.689)	(0.383)	(51.276)	(3.576)	(4.218)	(3.744)	(0.336)	(0.296)	(46.243)	(36.127)	(3.936)	(2.983)		
WG	0.250*	−1.394	0.287	15.486	0.621	−9.114*	−1.615	−0.165	0.069	92.973*	30.735**	−1.188	0.222	0.160	2.267
73:6–90:12	(0.090)	(1.473)	(0.373)	(24.669)	(3.583)	(3.717)	(1.396)	(0.324)	(0.328)	(40.907)	(16.339)	(3.496)	(3.516)		

Note: * and ** denote statistical significance levels at 5% and 10% respectively. Standard errors are in parentheses.

V. GARCH IN MEAN MODEL AND FOREIGN EXCHANGE RISK PREMIUM

Although we have some success in modelling the risk premium by generating conditional volatility with high frequency data, an implicit assumption is made about the stability of process over the entire sample period. What if the conditional volatility follows a time-dependent path? An alternative for generating conditional variances and standard deviations of currency returns is to use the general autoregressive heteroscedasticity models. It is generally recognized that heteroscedasticity exists in exchange rate series, especially for higher frequency series (Diebold and Nerlove, 1985; Baillie and Bollerslev, 1990). To examine the impact of conditional volatility on currency risk premium, a GARCH in mean specification should be considered for further refinement of empirical estimations. A general form of GARCH in Mean (GARCH-M) model can be presented as:

$$s_{t+1}-f_t=\beta_0+\beta_1 E(\sigma^p_{m,t+1})+\beta_2 U(\sigma^p_{m,t+1})+\beta_3 E^p(\sigma_{m*,t+1}) + \beta_4 U(\sigma^p_{m*,t+1})+\beta_5 h^p_{t+1}+\varepsilon_{t+1} \qquad (7)\text{-}(8)$$

$$\varepsilon_{t+1}\longrightarrow N(0,h^2_{t+1})$$

$$h^2_{t+1}=\rho_0+\sum_{i=0}^{m}\rho_{i+1}\varepsilon^2_{t-i}+\sum_{j=0}^{l}\delta_{j+1}h^2_{t-j}$$

Since it has been strongly suggested in the literature (Bollerslev *et al.*, 1992; Engle and Ng, 1993) that a GARCH(1,1) model, a parsimonious one, is able to capture time varying volatility of asset prices quite well, we choose to adopt the GARCH(1,1). For a GARCH(1,1) model, l and m both take value of 0. In this specification, in addition to conditioning the excess returns on the expected and unexpected volatility from the two relevant stock markets, we also include conditional volatility in the currency market governed by a standard GARCH process. Estimates of the model in Equations 7 through 8 are obtained by maximizing the log-likelihood function given the assumption that ε_{t+1} is conditionally normally distributed. We also try to differentiate the impact of volatility measured by standard deviations $(p=1)$ versus those measured by variances $(p=2)$. In order to satisfy the non-negativity constraints for the conditional volatility, all of the coefficients in the variance equation have to be positive or zero. It is also expected that the summation of ρ and δ should be less than one to insure a stationary system.[7]

The empirical results for GARCH(1,1) using standard deviation in the conditional mean equation are reported in Panel A of Table 4. Panel B of Table 4 displays the results when risk is measured by variances.

The results in Table 4 suggest that the GARCH model does a much better job in modelling the conditional volatility of exchange rates. Variability in exchange rates does have a strong impact on the conditional mean of the risk premium. The only exception is the Canadian dollar case, in which no statistical significance is found when h^2_t is used in Equation 7. Most of the coefficients take positive sign. Thus the results are consistent with a market where combined hedging activities of importers, exporters, and investors result in a net excess supply for forward sales of a foreign currency. Speculators taking long positions in the forward market are rewarded with risk premium. This is true for the Canadian dollar, British pound, and Deutsche mark. However, the story is quite different for the case of the Japanese yen, for which a risk premium is rewarded to speculators taking short positions in the yen forward market. With the bilateral trade balance mounting at several billion dollars for many years in our sample, the Japanese exporters have the need to hedge their dollar denominated export receipts in the forward market. Risk-averse speculators, however, would be expected to take short positions. The risk premium for selling yen in the forward market increases when the yen/dollar currency is highly volatile.

[7] In the event that the summation of ρ and δ is equal to one, the variance series is integrated of order 1.

Table 4. *Foreign exchange risk premium and volatility – GARCH in mean model*
Panel A. Standard deviations of equity markets and conditional volatility of currency market

$s_{t+1} - f_t = \beta_0 + \beta_1 E(\sigma_{m,t+1}) + \beta_2 U(\sigma_{m,t+1}) + \beta_3 E(\sigma_{m*,t+1}) + \beta_4 U(\sigma_{m*,t+1}) + \beta_5 h_{t+1} + \varepsilon_{t+1}$
$\varepsilon_{t+1} \rightarrow N(0, h^2_{t+1})$
$h^2_{t+1} = \rho_0 + \rho_1 \varepsilon^2_t + \delta_1 h^2_t$

Country	β_0	β_1	β_2	β_3	β_4	β_5	ρ_0	ρ_1	δ_1
Canada	−0.046*	−0.118*	−0.103*	0.215*	0.074	3.381*	0.007E-02*	0.046*	0.431*
73:6–90:12	(0.001)	(0.020)	(0.054)	(0.018)	(0.059)	(0.069)	(0.003E-03)	(0.022)	(0.022)
Japan	0.000	0.254*	−0.038	0.049	0.035	−0.335*	0.004E-02*	0.097*	0.885*
76:1–90:12	(0.002)	(0.058)	(0.142)	(0.051)	(0.132)	(0.074)	(0.004E-03)	(0.016)	(0.014)
UK	−0.030*	−0.004	0.162*	−0.148*	−0.063	1.234*	0.002E-01*	0.173*	0.624*
73:6–90:12	(0.001)	(0.028)	(0.094)	(0.031)	(0.102)	(0.042)	(0.002E-02)	(0.017)	(0.018)
WG	−0.023*	0.419*	0.409*	−0.531*	−0.065	0.875*	0.001*	0.133*	0.000
73:6–90:12	(0.002)	(0.056)	(0.159)	(0.049)	(0.136)	(0.068)	(0.009E-02)	(0.066)	(0.001)

Panel B. Variance of stock market and conditional volatility of currency market

$s_{t+1} - f_t = \beta_0 + \beta_1 E(\sigma^2_{m,t+1}) + \beta_2 U(\sigma^2_{m,t+1}) + \beta_3 E(\sigma^2_{m*,t+1}) + \beta_4 U(\sigma^2_{m*,t+1}) + \beta_5 h^2_{t+1} + \varepsilon_{t+1}$
$\varepsilon_{t+1} \rightarrow N(0, h^2_{t+1})$
$h^2_{t+1} = \rho_0 + \rho_1 \varepsilon^2_t + \delta_1 h^2_t$

Country	β_0	β_1	β_2	β_3	β_4	β_5	ρ_0	ρ_1	δ_1
Canada	−0.021	−0.775	−1.004	0.740	0.524	144.934	0.072E-03	0.047	0.447
73:6–90:12	(0.023)	(1.988)	(0.628)	(0.683)	(0.672)	(162.712)	(0.005E-02)	(0.075)	(0.368)
Japan	0.006**	0.749	0.960	1.055*	0.169	−7.668*	0.003E-02**	0.067	0.911*
76:1–90:12	(0.005)	(1.596)	(1.567)	(2.116)	(1.282)	(4.971)	(0.001E-02)	(0.038)	(0.042)
UK	−0.023*	−0.328	0.590	0.621	0.113	23.572*	0.002E-01*	0.096*	0.727*
73:6–90:12	(0.001)	(0.433)	(0.639)	(0.580)	(0.578)	(1.410)	(0.001E-02)	(0.011)	(0.011)
WG	−0.011*	1.822*	3.798*	−0.680	−0.477	6.639*	0.001*	0.113**	0.000
73:6–90:12	(0.002)	(0.861)	(1.204)	(0.564)	(0.701)	(1.998)	(0.001E-01)	(0.069)	(0.001)

Note: * and ** denote statistical significance levels at 5% and 10% respectively. Standard errors are in parentheses.

Apparently, the success of GARCH-M models depends on whether the conditional mean and variance equations are correctly specified. Inspired by recent findings about asymmetric impact of volatility on conditional means, we consider the possibility of separating the impact of positive shocks from negative shocks on the conditional variance. Glosten, Jagannathan, and Runkle (1993, GJR thereafter), Engle and Ng (1993) find that this variation of the standard GARCH model works much better for the stock market data. In particular, they find that positive shocks in excess return reduce the conditional volatility whereas the negative shocks or the bad news increase the conditional volatility.

Consider the case in foreign currency market, risk premium is not a universal phenomenon to all participants. The fact that volatility in the currency market can be driven by shocks from either country makes it difficult to explicitly state hypothesized impact. However, it will be of interest to see whether the negative and positive shocks in the mean influence the volatility differently and whether there is any consistent pattern. Hence, the following model is employed:

$$s_{t+1} - f_t = \beta_0 + \beta_1 E(\sigma^p_{m,t+1}) + \beta_2 U(\sigma^p_{m,t+1}) + \beta_3 E(\sigma^p_{m*,t+1}) + \beta_4 U(\sigma^p_{m*,t+1}) + \beta_5 h^p_{t+1} + \varepsilon_{t+1}$$

$$\varepsilon_{t+1} \rightarrow N(0, h^2_{t+1}) \qquad (9)\text{-}(10)$$

$$h^2_{t+1} = \rho_0 + \rho_1 \varepsilon^2_t + \rho_2 \varepsilon^2_t I_t + \delta_1 h^2_t$$

where $I_t = 1$ when ε_t is greater than or equals to 0, $I_t = 0$ when ε_t is less than 0. The difference between a positive and a negative shock in affecting the conditional variance can be examined by estimating the coefficient ρ_2 in addition to what we have estimated in the previous system. A negative (positive) coefficient suggests that positive innovation in the market results in a downward (upward) revision of h_{t+1} whereas the market reacts to negative shocks by revising its expectations on h_{t+1} upward (downward).

In the currency market, good news to investors in foreign countries may suggest the opposite to investors in the home country. Therefore, the sign for ρ_2 may not all be negative. Results for GJR model are reported in Panels A and B of Table 5, respectively. The improvements in estimates from this specification are apparent. The conditional volatility is significant in explaining the risk premium for all four currencies. This leads us to conclude that an asymmetry treatment of shocks is more effective in capturing the time varying characteristics of conditional volatility.

Table 5. *Foreign exchange risk premium and volatility – GJR GARCH-M model*
Panel A. Standard deviation of stock market and conditional volatility of currency market

$$s_{t+1} - f_t = \beta_0 + \beta_1 E(\sigma_{m,t+1}) + \beta_2 U(\sigma_{m,t+1}) + \beta_3 E(\sigma_{m*,t+1}) + \beta_4 U(\sigma_{m*,t+1}) + \beta_5 h_{t+1} + \varepsilon_{t+1}$$

$$\varepsilon_{t+1} \longrightarrow N(0, h^2_{t+1})$$

$$h^2_{t+1} = \rho_0 + \rho_1 \varepsilon_t^2 + \rho_2 \varepsilon_t^2 I_t + \delta_1 h_t^2$$

$I_t = 1$ when $\varepsilon_t \geq 0$, 0 when $\varepsilon_t < 0$

Country	β_0	β_1	β_2	β_3	β_4	β_5	ρ_0	ρ_1	ρ_2	δ_1
Canada	0.016*	0.037	−0.147*	0.207*	0.089	−2.428*	0.008E-02*	0.109*	−0.208*	0.385*
73:6–90:12	(0.001)	(0.095)	(0.050)	(0.106)	(0.061)	(0.385)	(0.007e-03)	(0.015)	(0.020)	(0.053)
Japan	0.011*	0.295**	0.016	−0.034	0.075	−0.544*	0.005E-02*	0.158*	−0.170*	0.892*
76:1–90:12	(0.005)	(0.167)	(0.153)	(0.192)	(0.159)	(0.195)	(0.002E-02)	(0.057)	(0.058)	(0.058)
UK	−0.020*	0.071	0.195**	−0.655*	−0.167	1.484*	0.006E-01*	0.000	0.561*	0.035
73:6–90:12	(0.009)	(0.198)	(0.114)	(0.322)	(0.124)	(0.361)	(0.002E-01)	(0.001)	(0.133)	(0.060)
WG	−0.061*	0.389*	0.459*	−0.674*	−0.068	2.278*	0.008E-01*	−0.092*	0.529*	0.133
73:6–90:12	(0.007)	(0.165)	(0.135)	(0.223)	(0.088)	(0.251)	(0.012E-02)	(0.025)	(0.033)	(0.103)

Panel B. Variance of stock market and conditional volatility of currency market

$$s_{t+1} - f_t = \beta_0 + \beta_1 E(\sigma^2_{m,t+1}) + \beta_2 U(\sigma^2_{m,t+1}) + \beta_3 E(\sigma^2_{m*,t+1}) + \beta_4 U(\sigma^2_{m*,t+1}) + \beta_5 h^2_{t+1} + \varepsilon_{t+1}$$

$$\varepsilon_{t+1} \longrightarrow N(0, h^2_{t+1})$$

$$h^2_{t+1} = \rho_0 + \rho_1 \varepsilon_t^2 + \rho_2 \varepsilon_t^2 I_t + \delta_1 h_t^2$$

$I_t = 1$ when $\varepsilon_t \geq 0$, 0 when $\varepsilon_t < 0$

Country	β_0	β_1	β_2	β_3	β_4	β_5	ρ_0	ρ_1	ρ_2	δ_1
Canada	0.006*	1.134	−0.807*	0.457	0.375	−69.120*	0.004E-02*	0.062	−0.181*	0.735*
73:6–90:12	(0.001)	(1.244)	(0.403)	(0.407)	(0.343)	(19.436)	(0.009E-03)	(0.039)	(0.044)	(0.077)
Japan	−0.001	28.796*	25.403*	−25.834*	−15.306*	2.156*	0.001*	0.347*	0.776*	0.000
76:1–90:12	(0.002)	(1.305)	(0.993)	(0.816)	(0.500)	(0.295)	(0.005E-02)	(0.052)	(0.226)	(0.000)
UK	−0.070*	−0.334	0.706	−0.033	−0.054	85.172*	0.008E-01*	0.008	0.227*	−0.103
73:6–90:12	(0.009)	(1.183)	(0.592)	(0.797)	(0.533)	(9.628)	(0.001E-01)	(0.004)	(0.037)	(0.115)
WG	−0.040*	1.732	3.926*	−0.611	−0.835	34.137*	0.001*	−0.108*	0.425*	0.000
73:6–90:12	(0.007)	(1.307)	(0.913)	(0.778)	(0.696)	(6.886)	(0.001E-01)	(0.020)	(0.107)	(0.006)

Note: GJR model proposed by Glosten *et al.* (1993) is a variation of the standard GARCH-M model. * and ** denote statistical significance levels at 5% and 10%, respectively. Standard errors are in parentheses.

Furthermore, we observe significant ρ_2 across all the currencies although the signs differ depending on the currency. For the Canadian dollar (also for the Japanese yen when standard deviation is used), it appears that a positive ε_{t+1} decreases the conditional volatility in the following period. On the other hand, the experience for the British pound, Deutsche mark and Japanese yen (when risk is measured by variance) suggests the opposite. A positive ε_{t+1} is responded by the market by revising its estimates on volatility upward.[8] Coincidentally, there seems to be agreement between the signs for coefficients β_5 and ρ_2. In addition to the significance related to currency market variables, stock market volatility (expected as well as unexpected, from both home and foreign countries) also appears to have a much more significant impact on the currency market risk premium than in the previous model.

VI. CONCLUDING REMARKS

The paper is another attempt in directly testing the relationship between exchange excess returns and *ex ante* volatility (Domowitz and Hakkio, 1985; Lyons, 1988). Different from previous research, we include not only the currency market volatility (both expected and unexpected) but also volatility from other important asset market, namely the stock market. Recent evidence on volatility spillover across various asset markets and market integration suggests that our approach is a necessary extension of previous findings. Moreover, our empirical model also intends to address the question of whether standard deviation or variance is the appropriate risk measure, and whether there is a need to include both terms in the risk premium equation. Based on results emerged from this study, we find that the forward excess return indeed can be significantly explained by risk measures. By using conditional volatility generated with high frequency data, it

[8] Frankel (1993) suggests that whether an increase in the variability in the spot rates would cause a rise (or a fall) in exchange rate depends on if the domestic country is a net creditor (a net debtor).

seems that volatility from stock markets is a much more important factor than the volatility from currency market. We also identify nonlinear relationships for the foreign exchange risk premiums of Japan, the UK, and West Germany.

However, when we relax the assumption that conditional forecasts are generated from a stable time series process, results are quite different. Further tests carried out by employing models in the GARCH family are in support of the existence of risk premiums. Specifically, volatility from currency market *pe se* does affect currency risk premium. A variation of the standard GARCH(1,1)-M model proves to be more successful in characterizing the conditional mean and volatility of foreign exchange risk premia than the conventional GARCH(1,1)-M model. The results indicate that positive shocks and negative shocks play a different role in the process of forming markets' expectations about future volatility. To be specific, for the Canadian dollar, Japanese yen (standard deviation as a measure of risk), we observe a downward revision of volatility when shocks in the conditional mean equation are positive. This is quite consistent with GJR's finding for the stock market. However, the results for the British pound, Deutsche mark, and Japanese yen (variance as a measure of risk) are contradictory to the proposition that 'good (bad) news' reduce (increase) market volatility.

The risk-aversion hypothesis is supported by our findings, suggesting that the speculative profit in the currency market is a reward for risk taking. The fact that both the *ex ante* volatility in the stock markets and those in the currency market contain useful information about the risk factor indicates that one can gain greater insight into asset behaviour if the multi-asset structural relationship is considered. Another important contribution of this study is that the relation between exchange risk premiums and the measures of *ex ante* volatility for some countries are nonlinear. This suggests that the use of only the standard deviation in the testing equation, as is used in the conventional approach, may be subject to a specification error. Needless to say, further reseach needs to be done in light of model specification and empirical refinements. Moreover, a large body of empirical research suggests that other elements such as the real interest rate differential, real exchange rate, and government intervention are important in explaining the exchange risk premium.

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