Review of International Economics, 11(1), 144–158, 2003

The Risk Premium, Exchange Rate Expectations, and the Forward Exchange Rate: Estimates for the Yen–Dollar Rate

*Stuart Landon and Constance E. Smith**

Abstract

The hypothesis that the forward rate is an unbiased predictor of the future spot rate has been rejected in many empirical studies. The rejection of this hypothesis could occur because market behavior is inconsistent with rational-expectations or because there exists a risk premium. Equations describing the forward premium and the change in the exchange rate are estimated jointly, and tests of both the rational-expectations and no-risk-premium hypotheses are conducted. Empirical estimates, obtained using quarterly data for the yen–dollar exchange rate, reject the rational-expectations hypothesis and suggest that there exists a time-varying risk premium.

1. Introduction

The assumption that the forward exchange rate is an unbiased predictor of the future spot exchange rate is widely used in both theoretical and empirical studies. However, the forward rate unbiasedness hypothesis has been rejected in a large number of studies using data for many different countries and time periods (Engel, 1996; Froot and Thaler, 1990; Lewis, 1995). Underlying this hypothesis are the assumptions of no risk premium and rational expectations, where the latter implies that all information useful in predicting the exchange rate is incorporated in the forward premium. The rejection of the unbiasedness hypothesis indicates that one or both of these assumptions is not consistent with market behavior. If the rational-expectations hypothesis is rejected, this would suggest that markets are inefficient, while the presence of a time-varying risk premium would imply that changes in macroeconomic variables, such as asset supplies, can alter relative asset yields even if expectations are rational.

The aim of the analysis presented in this paper is to determine whether the forward-rate unbiasedness hypothesis has been rejected because market behavior is inconsistent with rational-expectations or because there exists a time-varying risk premium. The existing literature has generally examined the rational-expectations hypothesis or the hypothesis of a time-varying risk premium, but not both. For example, a large portion of the unbiasedness literature employs empirical tests that are conditional on the assumption that there is no time-varying risk premium (Bilson, 1981; Engel, 1996; Fama, 1984; Froot and Thaler, 1990; Lewis, 1995). Another strand of this literature imposes an exchange-rate expectations formation mechanism and then determines whether there exists a risk premium, where the risk premium is calculated as the difference between the forward premium and the forecast change in the exchange rate. Studies that employ survey data to obtain an exchange rate forecast include Froot and

* Landon: University of Alberta, Edmonton, Alberta, Canada T6G 2H4. Tel: 780-492-7632; Fax: 492-3300; E-mail: Stuart.Landon@ualberta.ca. Smith: University of Alberta, Edmonton, Alberta, Canada T6G 2H4. Tel: 780-492-5940; Fax: 492-3300; E-mail: Constance.Smith@ualberta.ca. We thank an anonymous referee for helpful comments on an earlier draft of this paper.

Frankel (1989), Frankel and Chinn (1993), and Cavaglia et al. (1994). Studies that use an estimating equation to derive expectations of the future spot exchange rate include Canova and Ito (1991) and Hai et al. (1997). While these studies often find evidence of a time-varying risk premium, they do not attempt to model the risk premium as a function of economic variables.

A related group of studies examines whether movements in the risk premium vary systematically with observed variables. The variables employed include asset stocks (Engel, 1994; Frankel, 1982; Lewis, 1988; Thomas and Wickens, 1993), and uncertainty, in the form of changes in the variances of exogenous variables such as government spending, monetary policy, or the rate of technological change (Baillie and Bollerslev, 1990; Hodrick, 1989). In the empirical implementation of these studies, rational exchange rate expectations are imposed by setting the predicted future exchange rate equal to the actual future exchange rate plus a random error. As a consequence, even though these studies have generally not found evidence of a time-varying risk premium, it is uncertain whether this is because there is no risk premium or because the form of the implementation of the rational-expectations assumption is inappropriate.

In contrast to much of the literature, Dominguez and Frankel (1993) attempt to model the risk premium as a function of observed economic variables without imposing rational expectations. To do this, they first generate an estimate of the forward exchange rate risk premium using data on the forward premium and forecasts of exchange rate changes from survey data. Dominguez and Frankel then estimate the impact of central bank intervention on the (generated) risk premium and find that this type of intervention has a significant impact on the risk premium associated with the dollar–mark forward exchange rate.

In this paper, the Japanese yen–US dollar forward premium is decomposed into two components: a risk premium and the expected change in the exchange rate. The risk premium is modeled as a function of observed economic variables where, to be consistent with theoretical models of asset choice with risk-averse investors, the variables used include money supplies, as in Dominguez and Frankel (1993), as well as other potentially important asset stocks such as bonds and equities. Unlike in Dominguez and Frankel's paper, the second component of the forward-premium, the expected exchange rate change, is generated from a forecasting equation. The forecasting equation, and the equation describing the forward premium, are estimated jointly, with the exchange rate forecasting equation used to replace the expected exchange rate change variable in the forward-premium equation. This methodology is similar to that used by Leiderman (1980) to test monetary neutrality and rational expectations. The joint estimation of the exchange-rate and forward-premium equations makes it possible to test the cross-equation restrictions implied by the rational-expectations hypothesis, to estimate the risk premium and determine whether it is time-varying, and avoids the problems associated with survey data (Takagi, 1991).

2. Theoretical Background

One of the most important models that incorporates a time-varying risk premium in the forward exchange rate is Solnik's (1974) extension of the single-period capital asset pricing model to an international setting. This model has provided a theoretical basis for many empirical studies, including Engel (1994), Frankel (1982), Glassman and Riddick (1996), Lewis (1988), and Thomas and Wickens (1993). In this type of model, investors choose optimal portfolio shares to maximize expected utility, where the latter is a function of the mean and variance of end-of-period real wealth. The expected return on domestic and foreign currency bonds differs by a risk premium as a result of investor risk aversion. Thus, the risk premium, ρ, can be defined as:

$$\rho_t \equiv i_t^d - i_t^f - \Delta s_{t+1}^e, \tag{1}$$

where the right-hand side is the difference between the expected return on domestic and foreign bonds, i^d and i^f are the nominal one-period returns in local currency on domestic and foreign currency bonds, respectively, s is the log of the domestic currency price of one unit of foreign currency, and $\Delta s_{t+1}^e \equiv \mathrm{E}_t(s_{t+1}) - s_t$ is the one-period expected rate of change in the domestic currency price of foreign currency.

The covered interest rate parity condition implies that the forward premium equals the difference between the returns on domestic and foreign currency bonds:

$$f_t - s_t = i_t^d - i_t^f, \tag{2}$$

where f is the log of the one-period forward exchange rate. Using equation (1) to substitute for $(i_t^d - i_t^f)$ in (2) yields an equation that describes the forward premium as the sum of two components—the expected change in the exchange rate, Δs_{t+1}^e, and the risk premium, ρ_t:

$$f_t - s_t = \Delta s_{t+1}^e + \rho_t. \tag{3}$$

Because Δs_{t+1}^e and ρ_t are not directly observable, it is necessary to identify the factors that determine these variables.

Potential determinants of ρ_t can be identified using the model of international portfolio choice outlined by Glassman and Riddick (1996). As shown in Landon and Smith (1999), a model of this type predicts that the risk premium will vary with the supplies of all assets (the world market portfolio) and with the wealth of all countries:

$$\rho_t = \rho(\mathbf{x}_t^m, \mathbf{W}_t, \overline{W}_t), \tag{4}$$

where $\mathbf{x}^m$ is a vector of the world market portfolio of all assets, $\mathbf{W}$ is a vector of national wealth levels, and $\overline{W}$ is total world wealth.

Given (4), the forward premium equation, (3), can be rewritten as:

$$f_t - s_t = \Delta s_{t+1}^e + \rho(\mathbf{x}_t^m, \mathbf{W}_t, \overline{W}_t). \tag{5}$$

The next section describes empirical tests of the restrictions on the parameters of equation (5) that are implied by the rational-expectations and no-risk-premium hypotheses.

3. Empirical Implementation

As explained above, the hypothesis of forward exchange rate unbiasedness involves two assumptions: that expectations are rational, in the sense that the forecast of the change in the exchange rate utilizes all information that is useful in forecasting the exchange rate, and that there is no risk premium. To conduct empirical tests of these hypotheses, consider the following linearized version of the forward premium equation, (5):

$$f_t - s_t = \alpha + \Delta s_{t+1}^e + \boldsymbol{\gamma}'\mathbf{Z}_t + \varepsilon_t^r, \tag{6}$$

where α is a constant, $\mathbf{Z}_t$ is a vector of variables that determine the time-varying risk premium, $\boldsymbol{\gamma}$ is a vector of parameters, ε_t^r is a random error, and $\alpha + \boldsymbol{\gamma}'\mathbf{Z}_t + \varepsilon_t^r$ is a linearization of $\rho(\mathbf{x}_t^m, \mathbf{W}_t, \overline{W}_t)$.

To estimate equation (6) and test the rational-expectations hypothesis, it is necessary to specify an equation describing the expected change in the exchange rate, Δs^e_{t+1}. Suppose the actual change in the exchange rate from period t to period $t + 1$ can be expressed as:

$$\Delta s_{t+1} = \mathbf{b}'\mathbf{V}_t + \varepsilon^s_{t+1}, \tag{7}$$

where $\mathbf{V}_t$ is a vector of variables known at time t that forecast the future value of the exchange rate, $\mathbf{b}$ is a vector of parameters, and ε^s_{t+1} is a random error with mean zero. The expected exchange rate change, Δs^e_{t+1}, is obtained by taking the expectation at time t of equation (7). This expectation is then substituted into the forward rate equation, (6), to yield an equation for the forward premium that is a function of observable variables only:

$$f_t - s_t = \alpha + \boldsymbol{\beta}'\mathbf{V}_t + \boldsymbol{\gamma}'\mathbf{Z}_t + \varepsilon^r_t. \tag{8}$$

The rational-expectations hypothesis implies that the parameter vector $\mathbf{b}$ that enters the exchange rate equation (7) is the same as the parameter vector $\boldsymbol{\beta}$ in the forward premium equation. Hence, rational expectations can be tested by estimating (7) and (8) jointly and testing the cross-equation restrictions:

$$\boldsymbol{\beta} = \mathbf{b}. \tag{9}$$

If this restriction is rejected, the expected exchange rate that enters the forward premium equation is not consistent with the process determining the exchange rate and forward market participants will be making systematic expectational errors. The rational-expectations hypothesis also requires that the expectation error, ε^s_{t+1}, be orthogonal to all information available in period t. If the cross-equation restriction is not rejected, but this orthogonality condition is violated, market behavior is again not consistent with rational expectations.

The hypothesis of no time-varying risk premium implies that the forward premium is not affected by the variables included in the vector $\mathbf{Z}_t$. In other words, this hypothesis imposes the following restrictions on (8):

$$\boldsymbol{\gamma} = \boldsymbol{\iota}0, \tag{10}$$

where $\boldsymbol{\iota}$ is a vector of ones. The hypothesis of no risk premium, either constant or time-varying, imposes the joint restrictions:

$$\boldsymbol{\gamma} = \boldsymbol{\iota}0, \quad \alpha = 0. \tag{11}$$

4. Data and Empirical Results

The model of the forward premium described by equations (7) and (8) is estimated using a sample of quarterly data for the US and Japan that begins in 1975Q2, the period in which some of the data are first available, and ends in 1994Q1. A noticeable characteristic of the data is that there is much greater volatility in the exchange rate than in the forward premium. The standard deviation of the forward premium ($f_t - s_t$) is 0.8% per quarter, while the standard deviation of the change in the exchange rate ($s_{t+1} - s_t$) is 6.1% per quarter.

Before the forward premium equation can be estimated, it is necessary to determine the variables that form the elements of the vector $\mathbf{Z}_t$ in the risk premium equation. In previous studies that attempt to model the risk premium, the asset stocks used to determine the risk premium have included money (Dominguez and Frankel, 1993), government bonds (Frankel, 1982; Lewis, 1988), or government bonds and equities (Engel, 1994; Thomas and Wickens, 1993). To allow for a very general model of risk premium determination, the vector $\mathbf{Z}_t$ includes the stocks of US and Japanese money (M^{US}, M^{J}), government bonds (B^{US}, B^{J}), and equities (A^{US}, A^{J}). Owing to the growth in the nominal magnitudes of these variables over the sample period, these asset stocks were included in real-difference form. The real current account balances of both countries (CA^{US}/P^{US}, CA^{J}/P^{J}) are also included in the risk premium equation to reflect the country-specific wealth effects that determine the risk premium (**W** in (4)).[1]

Exchange Rate Forecasts

Specification To estimate the forward premium equation, (8), it is necessary to choose a specification for the exchange rate forecasting equation, (7). To provide an indication of the sensitivity of the parameter estimates and test results to the form of the exchange rate forecasting equation, three different exchange rate forecasting models are employed.

The first, and most general, exchange rate forecasting model used was obtained by considering for possible inclusion in the vector $\mathbf{V}_t$ of the forecasting equation, (7), a large number of variables that theoretical and empirical studies suggest may be important determinants of the exchange rate. These variables include the current and lagged changes in the real GDP of the US ($\Delta(Y^{US}/P^{US})$) and Japan ($\Delta(Y^{J}/P^{J})$), interest rates on short- and long-term US dollar and Japanese yen bonds (rs^{US}, rl^{US}, rs^{J}, rl^{J}), lagged values of the forward premium, lagged changes in the exchange rate, as well as the current and lagged values of the asset stock and wealth variables that are possible determinants of the risk premium (the elements of the vector $\mathbf{Z}_t$). To provide a parsimonious and efficient forecast, a sequential reduction procedure was employed to eliminate the many variables in the initial specification of the forecasting equation that did not contribute significantly to the forecast.[2]

The second specification employed for the exchange rate forecasting model, the "simple" specification, includes only lagged values of the change in the exchange rate as explanatory variables (that is, as elements of the vector $\mathbf{V}_t$). This form was motivated by survey studies that find traders in the foreign exchange market often rely on forecasts that are based on past trends in the exchange rate, particularly for short time horizons (Takagi, 1991; Taylor and Allen, 1992). One shortcoming of this type of forecast is that the forecast prediction error is likely to be correlated with variables that are observable at time t. If this is the case, the forecast will not be rational in the sense of using all available information. Nevertheless, by employing this type of forecast it is possible to examine whether the estimation results are sensitive to the use of very different forecasting equations.

The third exchange rate forecasting model used to estimate the forward premium equation assumes a "random walk" exchange rate forecast in which the current spot exchange rate is the forecast of the future spot rate. The use of a random-walk forecast by market participants would imply that the expected change in the exchange rate is zero. With this specification it is unnecessary to estimate a forecasting equation since $\Delta s^e_{t+1} = \boldsymbol{\beta}'\mathbf{V}_t$ is set to zero in the forward premium equation (8). One justification for using a random-walk forecast is the empirical evidence that most structural models of the exchange rate provide little improvement over a random-walk forecast, especially at short horizons (Frankel and Rose, 1995). As with the simple forecast model that incorporates only lagged values of the exchange rate, a random-walk forecast is unlikely to satisfy the orthogonality criteria of rational expectations.

Estimates of the exchange rate forecasting equations Estimates of the first two exchange rate forecasting models described above, the "general" and "simple" models, respectively, are presented in Table 1. As the results indicate, the estimates of the parameters of both models are not rejected by a number of diagnostic tests, although the general model explains a far greater proportion of the variation in the exchange rate change than does the simple model.

Using the general forecasting model, out-of-sample one-quarter-ahead forecasts of the exchange rate for the last five years and last ten years of the sample yield forecasts with a lower mean squared error and a lower mean absolute error than a random-walk forecast. (See Landon and Smith (1999) for detailed results.) Figure 1 graphs the actual change in the exchange rate and the change predicted by the general and simple models, respectively. The general forecast model tracks the changes in the exchange rate relatively well in comparison to the simple forecast, and particularly well in comparison to a random-walk model which would predict the future change in the exchange rate to always be zero.

Estimates of the Forward Premium Equation

As discussed in section 3, it is possible to test the hypotheses of rational expectations and no risk premium by testing restrictions on the parameters of equations (7) and (8), the exchange rate forecasting and forward premium equations, respectively. To do this, it is necessary to jointly estimate the forward premium equation and the exchange rate forecasting equation. Table 2 reports the maximum-likelihood estimates of the coefficients of the forward premium equation, the parameter vector $\boldsymbol{\gamma}$ in (8), when the cross-equation restrictions implied by the rational-expectations assumption are imposed. Estimates are reported for each of the three exchange rate forecasting models: the general exchange rate forecast, the simple exchange rate forecast, and the random-walk forecast. To be consistent with Eichenbaum and Evans' (1995) finding of slow adjustment in the exchange rate and interest rates, four lags of the risk premium variables were initially included in the forward premium estimating equation. However, to obtain a more parsimonious specification, a sequential lag reduction procedure, as described in Landon and Smith (1999), was used to reduce the number of lagged variables. As indicated in Table 2, the estimates explain a large proportion of the variation in the forward premium and provide no evidence of serial correlation (at the 1% significance level), heteroskedasticity, or structural change. As well, normality of the residuals is not rejected (at the 1% significance level) in two of the three cases.[3]

There are many similarities in the estimated risk premium parameters associated with the three different forecasting equations. This robustness of the estimates of the risk premium parameters to changes in the variables included in the exchange rate forecasting equation suggests that the variables determining the risk premium are not acting as proxies for variables that have been omitted from one of the exchange rate forecasting equations, but included in one of the others.[4]

Tests of the Rational-Expectations and No-Risk-Premium Hypotheses

Tests of the rational-expectations hypothesis The rational-expectations hypothesis—that all information useful in predicting the exchange rate is incorporated in the forward premium—is examined by testing the cross-equation restrictions given in equation (9). These restrictions imply that the elements of the parameter vector **b** in

Table 1. Estimates of the Exchange Rate Forecast Equation

	General forecast model	*Simple forecast model*
$\Delta(M^{US}/P^{US})^{o}$	0.4018*	
	(2.32)	
$\Delta(M^{US}/P^{US})^{o}_{-3}$	–0.5381*	
	(3.34)	
Δrs^{US}_{-3}	–0.0140*	
	(3.37)	
Δrl^{US}_{-3}	0.0455*	
	(5.13)	
Δrl^{J}_{-2}	0.0278*	
	(3.06)	
$f_{-1} - s_{-1}$	–1.335*	
	(2.01)	
Δs		0.1465
		(1.26)
Δs_{-1}		–0.0539
		(0.46)
Δs_{-2}		0.0896
		(0.76)
Δs_{-3}		0.1433
		(1.21)
Δs_{-4}	–0.3024*	–0.2470*
	(3.10)	(2.09)
Constant	–0.0241*	–0.0128
	(3.25)	(1.71)
R^2	0.4675	0.0991
$\bar{R}^2$	0.4127	0.0347
AR(1) ($\chi^2(1)$)	0.06	0.92
AR(4) ($\chi^2(1)$)	1.57	0.01
AR(1,2,3,4) ($\chi^2(4)$)	1.99	1.08
RESET test (*t*-statistic)	1.94	1.11
Breusch–Pagan–Godfrey test	7.19	1.12
for heteroskedasticity (χ^2-statistic)	(7)	(5)
ARCH heteroskedasticity test	3.19	0.23
($\chi^2(1)$-statistic)		
Structural shift dummy (*t*-statistic)	0.82	1.39

Notes: *Indicates the parameter is significantly different from zero at the 95% confidence level.
The number in brackets below a test statistic is the number of degrees of freedom for the test.
For variable x_t, $\Delta x_t \equiv x_t - x_{t-1}$.
Estimation period: 1975Q2–1994Q1.
The superscript "O" on the money stock variables indicates that this is the most recent data that would have been observable at the time the forecast was made.
The test statistics for serial correlation (the AR tests) are calculated as the number of observations (N) multiplied by the R^2 from a regression of the residual from the forecasting equation on its lagged value(s) and the explanatory variables included in the forecasting equation.
The RESET test was calculated by adding the square of the predicted value from the forecasting equation to the vector $\mathbf{V}_t$, re-estimating the forecasting equation, and testing whether the square of the predicted value is significant.
The Breusch–Pagan–Godfrey test statistic for heteroskedasticity is calculated as the number of observations multiplied by the R^2 from a regression of the squared residuals from the forecasting equation on the explanatory variables included in the forecasting equation.
The ARCH test statistic is N multiplied by the R^2 from a regression of the squared residuals from the forecasting equation on a constant and the lagged squared residuals.
The significance of the structural shift dummy is a test of whether there was a shift in the constant term in the forecast equation halfway through the sample (after 1984Q3).
P^{US} and P^{J} are the US and Japanese price indices, respectively.

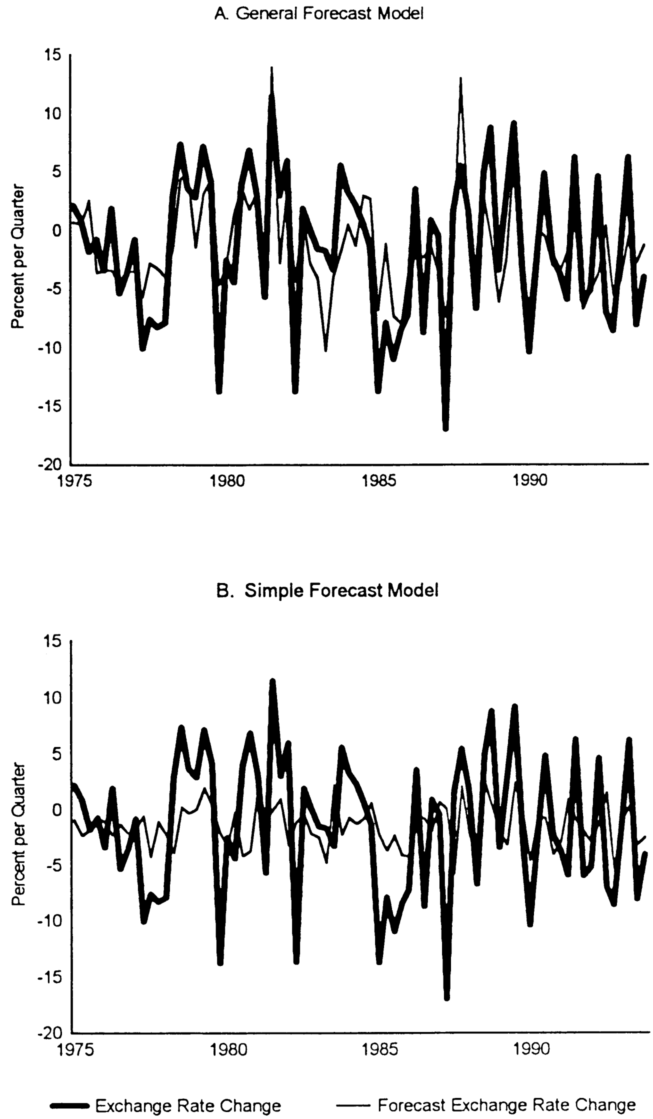

Figure 1. Actual and Forecast Exchange Rate Change

the exchange rate forecasting equation, (7), are equal to the elements of the parameter vector $\boldsymbol{\beta}$ in the forward premium equation, (8).

The cross-equation restrictions implied by the rational-expectations hypothesis are rejected at the 95% confidence level using the general exchange rate forecasting model.[5] This result implies that some information useful in predicting the exchange rate, information included in the general exchange rate forecasting equation, is not incorporated in the forward premium. If market participants had used this information, it would have been reflected in the forward premium and the cross-equation restrictions should not have been rejected.

When the simple exchange rate forecasting model is employed, the rational-expectations cross-equation restrictions are not rejected.[6] This finding is consistent with market participants incorporating a simple exchange rate forecast in the forward

Table 2. Estimates of the Forward Premium Equation

	Type of exchange rate forecast assumed		
	General forecast model	*Simple forecast model*	*Random-walk forecast model*
$\Delta(M^{US}/P^{US})$	0.0056	0.0274	0.0436*
	(0.32)	(1.32)	(2.05)
$\Delta(M^{US}/P^{US})_{-1}$		0.0095	0.0326
		(0.44)	(1.44)
$\Delta(M^{US}/P^{US})_{-2}$		0.0823*	0.0451*
		(4.26)	(2.06)
$\Delta(M^{J}/P^{J})$	–0.5423*	–0.4841*	–0.7506*
	(3.54)	(3.46)	(4.91)
$\Delta(M^{J}/P^{J})_{-1}$		–0.4070*	–0.3286*
		(3.03)	(2.52)
$\Delta(M^{J}/P^{J})_{-2}$		–0.3218*	–0.5036*
		(2.33)	(3.36)
$\Delta(A^{US}/P^{US})$	0.2181*	0.3153*	0.3495*
	(2.09)	(2.75)	(3.02)
$\Delta(A^{US}/P^{US})_{-1}$	–0.2108		–0.0504
	(1.80)		(0.52)
$\Delta(A^{US}/P^{US})_{-2}$	–0.0164		0.0431
	(0.18)		(0.43)
$\Delta(A^{US}/P^{US})_{-3}$	0.0024		0.2726*
	(0.02)		(2.71)
$\Delta(A^{US}/P^{US})_{-4}$	–0.1991*		
	(2.15)		
$\Delta(A^{J}/P^{J})$	–0.1974*	–0.2444*	–0.2167*
	(1.97)	(2.26)	(2.19)
$\Delta(A^{J}/P^{J})_{-1}$	0.3194*		
	(3.00)		
$\Delta(B^{US}/P^{US})$	0.1235*	0.1439*	0.0908
	(2.74)	(2.84)	(1.66)
$\Delta(B^{US}/P^{US})_{-1}$	–0.0383	–0.0447	
	(0.84)	(0.84)	
$\Delta(B^{US}/P^{US})_{-2}$	0.1929*	0.1281*	
	(3.76)	(2.58)	
$\Delta(B^{J}/P^{J})$	–0.00001	–0.0010*	–0.0012*
	(0.04)	(2.47)	(2.59)
$\Delta(B^{J}/P^{J})_{-1}$	–0.0001	–0.0008*	–0.0007
	(0.27)	(1.96)	(1.33)
$\Delta(B^{J}/P^{J})_{-2}$	–0.0014*	–0.0011*	–0.0009
	(3.22)	(2.41)	(1.61)
$\Delta(B^{J}/P^{J})_{-3}$	–0.0011*	–0.0018*	–0.0012*
	(2.77)	(4.49)	(2.49)
$\Delta(B^{J}/P^{J})_{-4}$	–0.0014*	–0.0014*	–0.0021*
	(3.33)	(3.55)	(3.94)
CA^{US}/P^{US}	–0.0828	–0.1382*	–0.2250*
	(1.61)	(1.98)	(2.97)
CA^{J}/P^{J}	–0.0035*	–0.0031*	–0.0029*
	(3.95)	(2.45)	(2.03)

Table 2. Continued

	Type of exchange rate forecast assumed		
	General forecast model	*Simple forecast model*	*Random-walk forecast model*
$(CA^J/P^J)_{-1}$		–0.0024	–0.0015
		(1.72)	(0.91)
$(CA^J/P^J)_{-2}$		–0.0011	–0.0006
		(0.74)	(0.31)
$(CA^J/P^J)_{-3}$		–0.0010	–0.0028
		(0.69)	(1.53)
$(CA^J/P^J)_{-4}$		0.0033*	0.0040*
		(2.89)	(2.88)
Q1	–0.0084*	0.0013	–0.0020
	(3.63)	(0.44)	(0.66)
Q2	–0.0035	–0.0024	–0.00001
	(1.79)	(0.94)	(0.004)
Q3	–0.0074*	–0.0051*	–0.0057*
	(3.87)	(2.24)	(2.14)
Constant	0.0207*	0.0266*	0.0155*
	(2.58)	(3.25)	(3.95)
R^2	0.8178	0.8096	0.7876
$\bar{R}^2$	0.6964	0.6678	0.6749
RESET (*t*-statistic)	1.00	1.70	0.58
AR(1) ($\chi^2(1)$)	1.72	0.87	0.22
AR(4) ($\chi^2(1)$)	3.94†	2.73	1.69
AR(1,2,3,4) ($\chi^2(4)$)	10.86†	9.04	7.80
Breusch–Pagan–Godfrey test for heteroskedasticity (χ^2-statistic)	35.96 (29)	31.25 (30)	33.08 (26)
ARCH heteroskedasticity test ($\chi^2(1)$-statistic)	0.18	1.94	1.42
Structural shift dummy (*t*-statistic)	0.002	1.66	0.63
Test of exclusion restrictions imposed by the lag length reduction procedure (χ^2-statistic)	25.76 (21)	14.51 (18)	15.12 (17)
Test of the normality of the residuals (χ^2-statistic)	11.51 (4)	15.12‡ (4)	6.15 (2)

Notes: The estimated parameters in this table correspond to the vector of parameters $\boldsymbol{\gamma}$ in equation (8) when the rational-expectations cross-equation restrictions (equation (9)) are imposed.
R^2 = One minus the ratio of the sum of squared residuals from the forward premium equation divided by the total sum of squares from this equation. $\bar{R}^2$ is calculated in the same fashion as R^2 except that the ratio that is subtracted from one is multiplied by $(N - 1)/(N - k)$, where N is the number of observations and k is the number of parameters in the forward premium equation.
† Indicates that the hypothesis of no serial correlation is rejected at the 5% significance level, but not at the 1% level.
‡ Indicates that the hypothesis of normality of the residuals is rejected at a 1% significance level. The normality test uses a multivariate extension, described in Richardson and Smith (1993), of the Jarque–Bera normality test.
See also notes to Table 1.

premium. However, this forecast does not include several variables that, from the construction of the general exchange rate forecasting specification, are known to be useful predictors of the exchange rate. In this sense, the model that uses the simple exchange rate forecast exhibits market inefficiency since it does not incorporate all available information in the forward premium.

Tests of the no-risk-premium hypothesis The hypotheses of no time-varying risk premium (equation (10)) and no constant or time-varying risk premium (equation (11)) are tested with and without the rational expectations cross-equation restrictions imposed. By examining both sets of test results it is possible to determine whether, if the no-risk-premium hypothesis is rejected when the rational-expectations cross-equation restrictions are imposed, this rejection occurs because the rational-expectations restrictions are inconsistent with the data.

The test results indicate that the no-risk-premium hypothesis is strongly rejected for all three cases whether or not the rational-expectations restriction is imposed.[7] These test results suggest that asset stocks and wealth levels have an important influence on the forward premium and are consistent with the many significant parameter estimates associated with the risk premium variables reported in Table 2. In particular, the Japanese and US money and equity variables and the Japanese and US current account (wealth) variables all have a significant effect on the forward premium.

The results discussed above indicate the presence of a time-varying risk premium that depends on asset stocks and changes in wealth. To illustrate the importance of the risk premium in the determination of the forward premium, Figure 2 graphs the actual forward premium and the estimated risk premium, where the latter is calculated using the parameter estimates ($\hat{\alpha} + \hat{\boldsymbol{\gamma}}'\mathbf{Z}_t$) from Table 2 associated with the general, simple and random-walk forecast models. As these figures clearly indicate, the predicted risk premium closely tracks actual *changes* in the forward premium in both direction and magnitude. In contrast, as shown in Figure 3, there is little relationship between the forward premium and the forecast change in the exchange rate using the general and simple exchange rate forecasts ($\hat{\mathbf{b}}'\mathbf{V}_t$) from Table 1.[8]

5. Concluding Comments

The findings of this paper provide evidence that may help to explain the consistent empirical rejection of the hypothesis of forward exchange rate unbiasedness. The results show, in the case of the yen–dollar exchange rate, that the rejection of this hypothesis can be attributed to *both* forward exchange market inefficiency (expectations are not rational) and a time-varying risk premium.

The estimation methodology employed in this paper makes it possible to estimate the independent effects of a risk premium and exchange rate expectations on the forward premium. This allows for a direct test of rational expectations (market efficiency). If market participants have rational expectations, information useful in predicting the exchange rate should be incorporated in the forward premium. The cross-equation restrictions associated with the rational-expectations hypothesis are not rejected using a simple exchange rate forecast based on lagged values of the exchange rate. However, with a more general forecast model that allows a large number of observable economic variables to enter the information sets of market participants, the cross-equation restrictions are rejected.

The rejection of the rational-expectations cross-equation restrictions for the model that employs the general exchange rate forecast suggests that information useful in

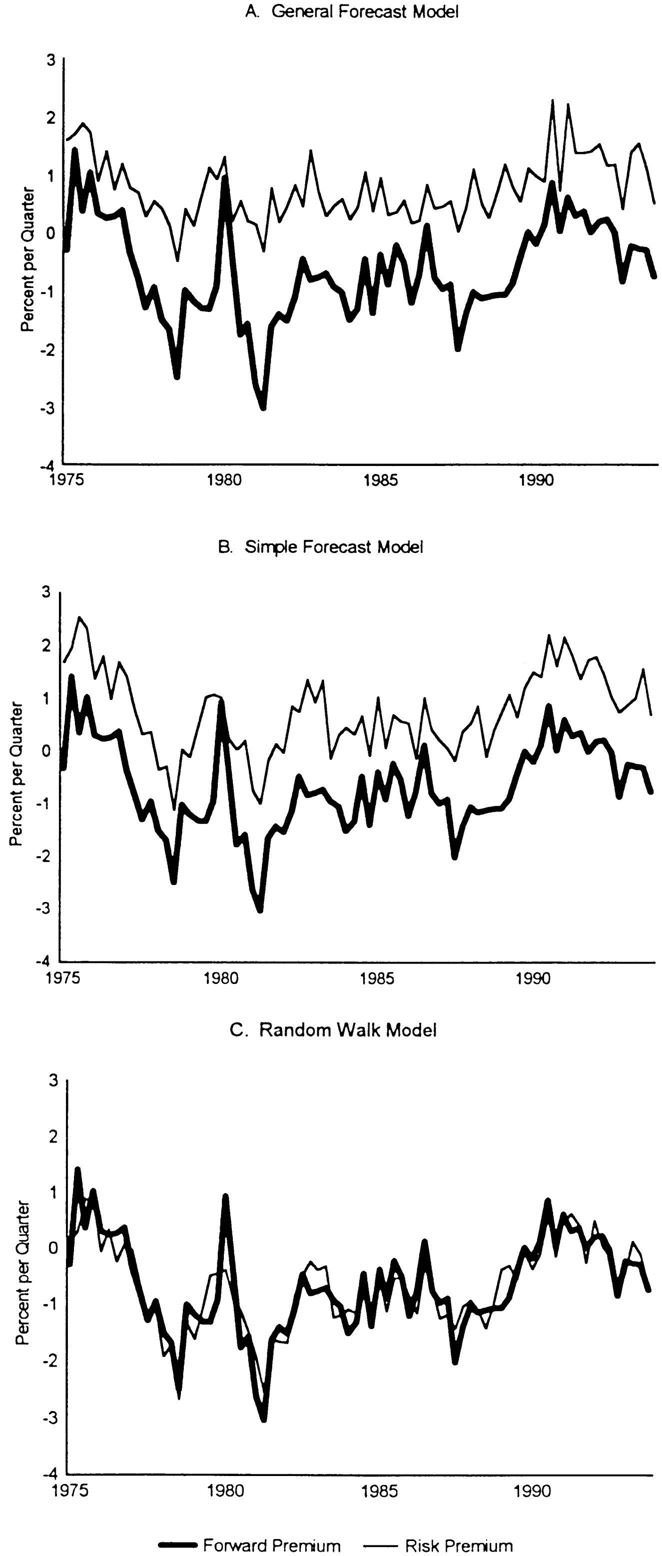

Figure 2. The Forward Premium and the Risk Premium

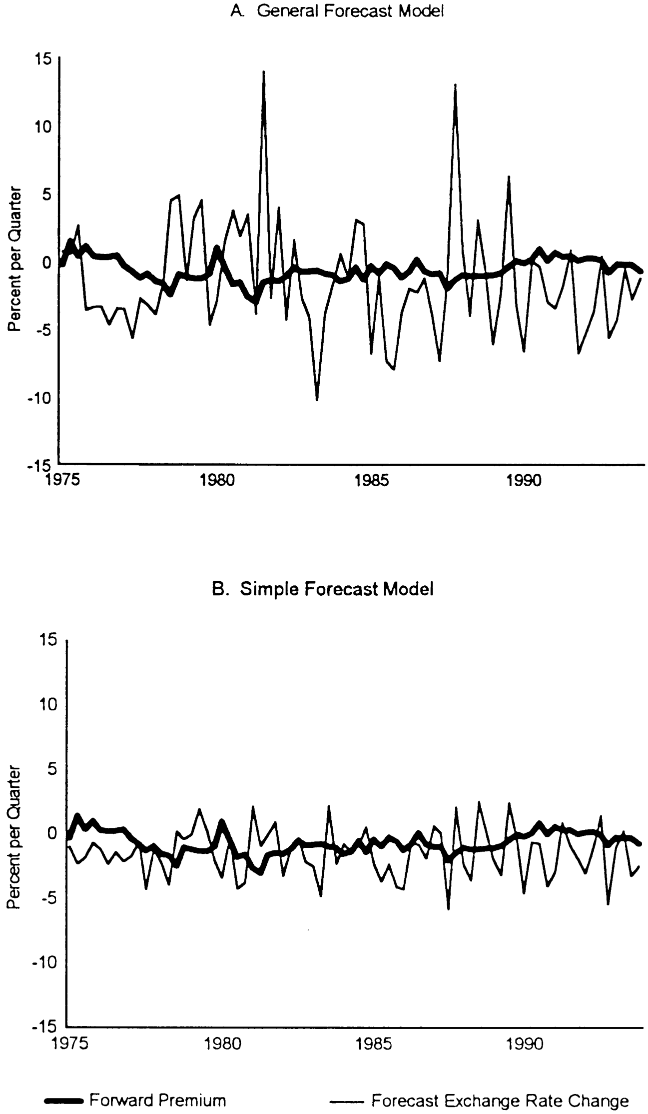

Figure 3. The Forward Premium and the Forecast Exchange Rate Change

predicting the exchange rate is not being incorporated in the forward premium. While the cross-equation restrictions are not rejected for the simple forecast model, this model does not include several variables that are known to be useful in predicting the exchange rate. Thus, the results for both forecast models suggest there is some inefficiency in the forward exchange market.

The empirical results reported above reject the hypothesis of no time-varying forward exchange rate risk premium for three different specifications of the exchange rate forecasting equation, both with and without rational expectations imposed. The time-varying risk premium found here is shown to vary with changes in asset supplies and wealth, as predicted by theories of international portfolio allocation with risk-averse assetholders.

The results reveal a close and robust relationship between the risk premium and the forward premium. This, plus the finding that the forecast of the change in the exchange rate bears little relationship to the forward premium, suggests that most of the variation in the dollar–yen forward premium results from changes in the risk premium rather than from changes in the expected exchange rate.

References

Baillie, Richard T. and Tim Bollerslev, "A Multivariate Generalized ARCH Approach to Modeling Risk Premia in Forward Foreign Exchange Rate Markets," *Journal of International Money and Finance* 9 (1990):309–24.

Bilson, John F. O., "The 'Speculative Efficiency' Hypothesis," *Journal of Business* 54 (1981): 435–51.

Canova, Fabio and Takatishi Ito, "The Time-Series Properties of the Risk Premium in the Yen/Dollar Exchange Market," *Journal of Applied Econometrics* 6 (1991):125–42.

Cavaglia, Stefano M. F. G., Willem F. C. Verschoor, and Christian C. P. Wolff, "On the Biasedness of Forward Foreign Exchange Rates: Irrationality or Risk Premia?" *Journal of Business* 67 (1994):321–43.

Dominguez, Kathryn M. and Jeffrey A. Frankel, "Does Foreign-Exchange Intervention Matter? The Portfolio Effect," *American Economic Review* 83 (1993):1356–69.

Eichenbaum, Martin and Charles L. Evans, "Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates," *Quarterly Journal of Economics* 110 (1995):975–1009.

Engel, Charles, "Tests of CAPM on an International Portfolio of Bonds and Stocks," in Jeffrey A. Frankel (ed.), *The Internationalization of Equity Markets*, Chicago: University of Chicago Press (1994):149–72.

———, "The Forward Discount Anomaly and the Risk Premium: a Survey of Recent Evidence," *Journal of Empirical Finance* 3 (1996):123–92.

Fama, Eugene F., "Forward and Spot Exchange Rates," *Journal of Monetary Economics* 34 (1984):319–38.

Frankel, Jeffrey A., "In Search of the Exchange Risk Premium: a Six-Currency Test Assuming Mean-Variance Optimization," *Journal of International Money and Finance* 1 (1982):255–74.

Frankel, Jeffrey A. and Menzie D. Chinn, "Exchange Rate Expectations and the Risk Premium: Tests for a Cross Section of 17 Currencies," *Review of International Economics* 1 (1993): 136–44.

Frankel, Jeffrey A. and Andrew K. Rose, "Empirical Research on Nominal Exchange Rates," in Gene M. Grossman and Kenneth Rogoff (eds.), *Handbook of International Economics*, Vol. 3, Amsterdam: North-Holland (1995):1689–729.

Froot, Kenneth A. and Jeffrey A. Frankel, "Forward Discount Bias: Is it an Exchange Risk Premium?" *Quarterly Journal of Economics* 104 (1989):139–61.

Froot, Kenneth A. and Richard H. Thaler, "Anomalies: Foreign Exchange," *Journal of Economic Perspectives* 4 (1990):179–92.

Glassman, Debra A. and Leigh A. Riddick, "Why Empirical International Portfolio Models Fail: Evidence that Model Misspecification Creates Home Asset Bias," *Journal of International Money and Finance* 15 (1996):275–312.

Hai, Weike, Nelson C. Mark, and Yangru Wu, "Understanding Spot and Forward Exchange Rate Regressions," *Journal of Applied Econometrics* 12 (1997):715–34.

Hodrick, Robert J., "Risk, Uncertainty, and Exchange Rates," *Journal of Monetary Economics* 23 (1989):433–59.

Landon, Stuart and Constance E. Smith, "The Risk Premium, Exchange Rate Expectations, and the Forward Exchange Rate: Estimates for the Yen–Dollar Rate," University of Alberta working paper 99-2 (1999).

Leiderman, Leonardo, "Macroeconometric Testing of the Rational Expectations and Structural Neutrality Hypotheses for the United States," *Journal of Monetary Economics* 6 (1980):69–82.

Lewis, Karen K., "Testing the Portfolio Balance Model: a Multi-Lateral Approach," *Journal of International Economics* 24 (1988):109–27.
———, "Puzzles in International Financial Markets," in Gene M. Grossman and Kenneth Rogoff (eds.), *Handbook of International Economics*, Vol. 3, Amsterdam: North-Holland (1995): 1913–71.
Richardson, Matthew and Tom Smith, "A Test for Multivariate Normality in Stock Returns," *Journal of Business* 66 (1993):295–321.
Solnik, Bruno H., "An Equilibrium Model of the International Capital Market," *Journal of Economic Theory* 8 (1974):500–24.
Takagi, Shinji, "Exchange Rate Expectations: a Survey of Survey Studies," *International Monetary Fund Staff Papers* 38 (1991):156–83.
Taylor, Mark P. and Helen Allen, "The Use of Technical Analysis in the Foreign Exchange Market," *Journal of International Money and Finance* 11 (1992):304–14.
Thomas, S. H. and M. R. Wickens, "An International CAPM for Bonds and Equities," *Journal of International Money and Finance* 12 (1993):390–412.

Notes

1. All data are from the IMF's *International Financial Statistics* except the government bond data, which are from the OECD's *Financial Statistics Monthly*, Tables A.163/21, D/21, I.C.3/07, and D/07. For more detail see Landon and Smith (1999).
2. A complete description of the methodology used to determine the final specification of this "general" forecasting equation is given in Landon and Smith (1999).
3. The hypothesis that the forward premium is nonstationary (has a unit root) is also rejected.
4. As another check that the significant risk premium variables (the variables in the vector **Z**) are not proxying exchange rate forecasting effects, these variables were added individually into each of the exchange rate forecasting equations. None of the variables that would be observable in the current period were found to be significant determinants of the exchange rate. As well, if the lagged forward premium is added as an explanatory variable to the forward premium equation, it is not significant if rational expectations is not imposed.
5. The χ^2 likelihood-ratio test statistic associated with the test of $\mathbf{b} = \boldsymbol{\beta}$ is 50.72 with 7 degrees of freedom.
6. The χ^2 likelihood-ratio test statistic associated with the test of $\mathbf{b} = \boldsymbol{\beta}$ is 7.19 with 5 degrees of freedom.
7. The χ^2 likelihood-ratio test statistic for the test of the no-risk-premium hypothesis when rational expectations is imposed for the general forecasting model in the case of (i) no time-varying risk premium ($\boldsymbol{\gamma} = 0|\mathbf{b} = \boldsymbol{\beta}$) is 70.60(22) and (ii) no constant or time-varying risk premium ($\boldsymbol{\gamma} = 0$ and $\alpha = 0|\mathbf{b} = \boldsymbol{\beta}$) is 71.72(23), where the degrees of freedom for the test are given in brackets. Comparable test statistics for the simple forecast model are (i) 118.32(25) and (ii) 119.45(26). If the rational expectations restriction is *not* imposed, for the general forecasting model, the χ^2 likelihood-ratio test statistic for the hypothesis of (i) no time varying risk premium ($\boldsymbol{\gamma} = 0$) is 69.30(22) and of (ii) no constant or time-varying risk premium ($\boldsymbol{\gamma} = 0$ and $\alpha = 0$) is 74.42(23). Comparable test statistics for the simple forecast model are (i) 117.52(25) and (ii) 151.21(26) while, for the random-walk model, they are (i) 117.80(26) and (ii) 155.80(27).
8. The correlations between the forward premium and the predicted risk premium range from 0.782 for the general forecasting model to 0.887 for the random-walk model. In contrast, the correlations between the forward premium and the forecast exchange rate change range from –0.280 to –0.069.