

Risk Premiums and the Forward Rate Anomaly: A Survey

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Abstract: Financial economists have intensely scrutinised whether forward currency markets reflect all relevant information. In a no-arbitrage environment, the twin assumptions of risk neutrality and rational expectations imply that the forward rate should be an unbiased predictor of realised future spot rates. This has been labeled the Unbiased Forward Rate Hypothesis (UFRH). Unfortunately, empirical support for the UFRH is unconvincing. Estimated coefficients are frequently of the wrong sign as predicted by theory. This empirical regularity has been termed, among others, the forward rate puzzle. Many have attempted to reconcile these anomalous findings with the Efficient Markets Hypothesis (EMH) – the notion of a market that impounds all relevant information into prices. However, a completely satisfactory explanation remains elusive. This paper aims to review how researchers have attempted to explain the forward rate puzzle, with particular emphasis upon how currency markets may inherently attract risk premiums, and how they may vary over time. Moreover, we examine Keynes’ proposition that inspired the insurance theory of speculation. This line of reasoning suggests that speculators are systematically rewarded for participating in markets. Although dated, interest in Keynes’ proposition remains. Subsequent research has found that speculators receive compensation for their actions. Furthermore, it is noted that relatively few have attempted to combine the insurance theory of speculation with the forward rate puzzle. Given the attention attributed to speculators in today’s financial markets, such a consideration is highly important in unraveling the mysteries of modern currency markets, particularly given the tumultuous world environment of the recent past.

Keywords: Unbiased forward rate; risk premium; speculation

1. INTRODUCTION

Alongside the equity premium puzzle, the forward rate anomaly remains one of the unsolved mysteries of financial economics. There have been many attempts to unravel this mystery, yet none appear completely satisfactory. This paper focuses upon the possible existence of a risk premium as a source of the puzzle. It provides a brief overview of previous attempts to capture this premium, as well as two apparently less common methods, namely application of a world capital asset pricing model, extending the form proposed by Sharpe (1964), and drawing inspiration from Keynes (1930), models that explicitly account for speculation.

2. THEORETICAL BACKGROUND

Modern finance theory is founded upon the exclusion of arbitrage. Application of these principles results in the well-known *covered* interest parity condition:

$$\frac{F_t^{t+1} - S}{S} = \frac{i^d - i^f}{1 + i^f} \quad (1)$$

Assuming risk neutrality, a similar relationship holds for expected future spot rates, which is labeled the *uncovered* interest parity relation:

$$\frac{S_t^{e,t+1} - S}{S} = \frac{i^d - i^f}{1 + i^f} \quad (2)$$

Thus, under our assumptions, the forward rate represents the market’s expectation of the future spot rate. Assuming expectations are rational such that subjective expectations are equated with mathematical expectations, we get:

$$E_t(S_{t+1}) = F_t^{t+1} \quad (3)$$

which implies:

$$S_{t+1} = F_t^{t+1} + \varepsilon_{t+1} \quad (4)$$

where ε is a zero-mean, white-noise process. Equation (4) delivers the unbiased forward rate hypothesis (UFRH). It implies the forward rate should be both an unbiased and optimal predictor of future spot exchange rates.

3. OVERVIEW OF EMPIRICAL TESTS

3.1 Early Empirical Studies

Tests of the UFRH have been contradictory. Early work was generally supportive of the UFRH and typically employed the following specification:

$$\ln S_{t+1} = \alpha + \beta(\ln F_t^{t+1}) + \varepsilon_{t+1} \quad (5)$$

Equation (4) illustrates that the null hypothesis is ($\alpha=0, \beta=1$). Indeed, studies generally find this version of the UFRH to be supported empirically.

However, subsequent research on unit roots drew doubt to the appropriateness of (5), as conventional wisdom takes exchange rates to display unit root behaviour.¹ Concerns over spurious regressions prompted researchers to look for stationary alternatives to (5). This resulted in the following specification:

$$\Delta \ln S_t = \alpha + \beta(\ln F_{t+1}^{t+1} - \ln S_t) + \varepsilon_{t+1} \quad (6)$$

where $\Delta \ln S_{t+1} = (\ln S_{t+1} - \ln S_t)$. Estimates of (6) overwhelmingly reject the UFRH across various time periods and currencies. A greater cause for concern though is the negative $\hat{\beta}$ frequently obtained from (6).² A negative $\hat{\beta}$ implies investors are better off investing in the currency with the higher interest rate. A higher interest rate is guaranteed and investors are likely to benefit from currency movements, as currencies with higher interest rates tend to appreciate.

These results spawned the “forward rate puzzle” because in today’s world of liquid capital flows it seems unlikely that the simple rule of “invest in the highest rate” has not been fully exploited. Table 1 provides representative results of tests of the forward spread as a predictor of future spot exchange rates. Researchers have proposed that the violations may not be economically significant enough to attract speculators. The interesting question is why this relationship arises at all?

3.2 Possible Explanations

There have been numerous responses to the anomalous results obtained from (6). Given the tendency for exchange rates to behave like unit roots, and developments in the application of cointegration techniques, misspecification of (6) was touted as a possible source of the puzzle. Barnhart and Szakmary (1991) and Zivot (2000) explored the possibility that misspecification caused these counter-intuitive findings. Cointegration methods were used for a richer description of the system’s dynamics. They

found contemporaneous forward and spot rates to be cointegrated with a cointegrating parameter near 1. Error-correction models were employed, accounting for lagged changes in forward and spot rates; the UFRH was still rejected.

Peso-problems are often cited for the failure of the UFRH. Peso-problems arise when at the time of decision-making, investors rationally expect the occurrence of a future event that fails to eventuate. The data will be suggestive of bias on the part of agents even if agents act rationally. This explanation appears unsatisfactory as the UFRH is rejected across a range of time periods and currencies, making it less likely that sample specific problems exist. Parameter instability across periods may also contribute to poor empirical results. If parameters are non-constant, then reliable inferences cannot be drawn from regressions over the entire period. Using five-year rolling regressions, Baillie and Bollerslev (2000) document considerable instability in $\hat{\beta}$, which became significantly negative over the mid-1980’s; a time when the USD underwent significant appreciation. Hence, tests of the UFRH should acknowledge the possibility of an unstable relationship.

Another explanation offered is that systematic errors in expectations introduce bias into the forward forecast error. Equation (3) shows that the UFRH is a joint hypothesis of rational expectations and risk neutrality. Hence, pinpointing the source of the violation is rather difficult. If the market makes systematic errors, $F_t \neq E_t(S_{t+1})$. Researchers have used survey data to test whether the expectations of market participants contain systematic errors. Survey expectations typically violate rationality.³ However, conjecture over survey studies arises because estimated expectations might not reflect true expectations, casting doubts upon the validity of survey-based results.

3.3 The Possibility of a Premium

Fama (1984) and Nieuwland *et al.* (2000) are just some attempts to reconcile the anomalous results with market efficiency by considering the possibility of a risk premium.⁴ The argument is that risk averse investors require compensation to assume risk. Relaxing risk neutrality, but maintaining rationality gives the following:

$$E_t(S_{t+1}) = F_t^{t+1} + \rho_t \quad (7)$$

$$S_{t+1} = F_t^{t+1} + \rho_t + \varepsilon_t \quad (8)$$

¹ Baillie and Bollerslev (1989) find $S_t, F_t \sim I(1)$.

² In their extensive survey, Froot and Thaler (1990) reported the mean of $\hat{\beta}$ to be -0.88.

³ Survey-based studies include Cavaglia, Verschoor and Wolff (1993) and Froot and Frankel (1989).

⁴ Engel (1996) gives a comprehensive review.

TABLE 1. SUMMARY OF FORWARD SPREAD ESTIMATES

$$\Delta S_t = \alpha + \beta(F_t - S_t) + \varepsilon_t$$

STUDY	PERIOD	$\hat{\beta}$	Significant at 5 % level
Fama (1984)			
- Japan	1973-82	-0.29	NO
- Switzerland		-1.14	NO
- U.K.		-0.90	NO
- Canada		-0.87	NO
Barnhart and Szakmary (1991)			
- Germany	1974-88	-3.63	YES
- U.K.		-1.65	YES
- Japan		-0.59	NO
- Canada		-2.02	YES
Bekaert and Hodrick (1993)			
- Germany	1975-89	-3.015	YES
- U.K.		-2.021	YES
- Japan		-2.098	YES

Equation (8) highlights the problem in testing for the presence of a risk premium. As with many economic relationships, theory often prescribes variables that are unobservable. While economic models can be used to incorporate risk premiums, failure to detect a risk premium may result from an inadequate model rather than the absence of a premium.

Researchers have employed numerous techniques to detect the presence of a risk premium within the forward market. Wolff (1987, 2000) employed a signal extraction approach based upon the Kalman filter to detect any deterministic component within the forward rate's prediction error. Wolff found the forward rate error to be well characterised by an AR(1) process, which allows him to extract systematic patterns. However, the presence of a systematic component is insufficient to conclude that such bias compensates agents for bearing risk. It could arise from the failure of rational expectations. Wolff's methodology precludes him from attributing these patterns to compensation for risk because he does not address why this predictability arises. The seminal work of Engle (1982) on Autoregressive Conditional Heteroscedasticity (ARCH), extended by Bollerslev (1986) and Engle, Lilien and Robbins (1987), sparked interest in whether volatility of the forecast error could unravel the forward rate puzzle. Their research precipitated the adoption of ARCH-in-Mean (ARCH-M) models within the literature. Financial economists

employ these models to capture the well-known observation that asset markets display periods of turbulence and tranquillity. Greater variation in returns creates a more uncertain investment climate. Thus, we expect risk premiums to increase with the conditional variance because risk averse investors will demand greater compensation in periods of above-average uncertainty (see, for example, Domowitz and Hakkio (1985)).

The ARCH-M model allows conditional volatility to directly influence the conditional mean, capturing our expectation that agents command a larger risk premium in more turbulent periods. Domowitz and Hakkio (1985), Baillie and Bollerslev (1990) and Bekaert and Hodrick (1993) find little evidence of a premium dependent upon the conditional variance of the forecast error.⁵ Several explanations have been offered. Volatility alone cannot explain which currency earns the premium, as agents on both sides of the market are subject to the same volatility. Thus, the model cannot answer why a currency attracts a premium. Moreover, Baillie and Bollerslev (1990) note the weak evidence may be data dependent. Monthly data is typically analysed, which they argue does not display strong conditional heteroscedasticity, relative to finer sampling intervals.

3.4 Systematic Risk and the Risk Premium

⁵ Baillie and Bollerslev, and Bekaert and Hodrick, use the constant correlation specification of a multivariate GARCH model. They cannot explain the forward puzzle with time-varying risk premiums.

The failure of data-based models to reconcile theory with observations led researchers to adopt more formal models of the risk premium. Such models make explicit why a currency attracts the premium it does. The literature comprises numerous theoretical and empirical models. For example, Hodrick (1981), Stulz (1981) and Lucas (1982), among others, derive intertemporal models, whereby forward contracts attract time-varying risk premiums. Such premia generally arise out of consumption risk.⁶ Cumby (1988) and Kaminsky and Peruga (1990) analysed the role for consumption risk as a determinant of forward premia. Consumption-based models typically fail empirical testing; Cumby (1988, p.297) declared that, ‘...the consumption-based model does not contain an adequate description of returns to forward speculation.’⁷ Generally, applications of consumption models have proved disappointing.

Relatively little published material directly employs the traditional mean-variance framework that led to the Capital Asset Pricing Model (CAPM), attributed to Sharpe (1964) and Lintner (1965), in tests of the UFRH.⁸ Despite its restrictive assumptions, which perhaps limit its relevance, and weak empirical support, the CAPM has been the workhorse of research into asset pricing. The standard CAPM posits a linear relationship between the expected return on the risky asset, k , and the expected return on the market portfolio of risky assets, m :

$$E(R_k) = r_f + \beta_k [E(R_m) - r_f] \quad (9)$$

where $\beta_k = \text{Cov}[R_m, R_k] / \text{Var}(R_m)$. The CAPM predicts that only that portion of an asset’s variance correlated with other risky assets deserves a risk premium because holding a well-diversified portfolio eliminates uncorrelated fluctuations. A tenet of modern portfolio theory (MPT) is that capital markets do not reward participants for engaging in unnecessary risks. Thus, if correlations between asset ‘ k ’ and other assets are weak, the risk premium interpretation is unsupported because MPT predicts that capital markets will not award premiums for bearing diversifiable risk.

Estimation of a CAPM has seen various data types and techniques applied within the literature, with early studies refuting the proposition of a risk premium within currency markets. Cornell and Dietrich (1978)

⁶ For more details see Engel (1996).

⁷ Kaminsky and Peruga (1990) found evidence of a time-varying foreign exchange premium, although they rejected the restrictions implied by the model.

⁸ In a footnote, Barnhart and Szakmary, (1991, p. 264) report little success by including world equity returns.

regressed currency returns upon the S&P 500, whereas Roll and Solnik (1977) regressed currency returns against a portfolio of currencies. Both papers found little evidence of systematic risk, yet both approaches are unsatisfactory. Under CAPM, the relevant benchmark is the market portfolio; portfolios of currencies and U.S. equity indices are unlikely to be fair representations. Furthermore, early studies ignored the possibility of time-varying phenomena, which subsequent research has shown to be an important characteristic of financial markets. Thus, the lack of systematic risk detected within currencies may also arise from the imposition of constant risk parameters.

Dissatisfied researchers addressed both the narrowness of the benchmark portfolio and time-varying risk. Mark (1988) and McCurdy and Morgan (1991, 1992) used returns to an international equity index, such as the Morgan Stanley Capital World Index (MSCWI). The use of a single domestic index effectively treats that market as an island, which is untenable in today’s environment. A global perspective seems most appropriate because from a currency market point-of-view, combined with the liberalisation of capital flows, international diversification is highly relevant. While this index omits assets like precious metals and human capital, it is commonly applied within the literature, although tests based upon a proxy market portfolio are subject to Roll’s Critique. Stulz (1981) noted that the world portfolio may be irrelevant for many investors. Rigidities such as differential taxes and costs may limit the usefulness of what is known as an ‘international CAPM’. Unfortunately little is known about how to model partially-integrated international markets (see, for example, Stulz (1995).

Advances in second-moment modelling and subsequent multivariate extensions facilitated the incorporation of time-varying risk. Bollerslev, Engle and Wooldridge (1988) were among the first to employ multivariate models that allowed components of the risk premium to exhibit time variation (in a domestic setting). These models are termed conditional asset pricing models. Conditional models allow investors to update their expectations as they receive new information. The standard CAPM, (9), is respecified as expectations for time t , conditional upon information available at time $t-1$.

Conditional models were applied to an international setting. Harvey (1991) utilised an international CAPM to explain differences in country returns. He found that time-varying covariances are important in explaining the cross-section of country equity portfolios. McCurdy and Morgan (1991, 1992), and Kho (1996) implemented the BEKK multivariate

GARCH technique to derive conditional betas and time-varying prices of risk. These studies reported evidence consistent with the presence of time-varying systematic risk in currency markets. Their results accord with findings by Harvey (1991), Ferson and Harvey (1991) and Bessembinder and Chan (1992), who propound the importance of time variation across different contexts. The literature clearly demonstrates not only that an investigation of currency premiums should allow for time-varying risk, but that ignoring the role for systematic risks via equity markets appears unreasonable.

3.5 Speculation and Backwardation

Keynes (1930) suggested that hedgers must pay speculators a premium for assuming risk, giving birth to the ‘backwardation’ or ‘insurance theory’ of speculation. Keynes’ theory predicts that long speculation will be profitable if $E_t(S_{t+1}) > F_t$ and *vice-versa* for when speculators are net short.⁹ Thus, if a premium exists, its direction will depend upon whether speculators are net long or short.

Although dated, interest in backwardation remains within the literature. Using reports of traders’ positions, Carter *et al.* (1983) and Chang (1985) discovered that speculators in agricultural commodity futures appeared to earn a premium. Bessembinder (1992) explored the relationship between changes in futures prices and net speculative positions to determine whether speculators were capable of predicting future price movements. He found that currency futures returns were positive when conditioned upon net speculative positions. In contrast, Kolb (1992) and Chatrath *et al.* (1997) concluded that the marginal speculator was unable to command a premium. These conflicting results illustrate that the theory remains highly contentious and its validity unresolved.

Although the above studies did not consider the forward rate puzzle, Bessembinder’s (1992) results indicate that Keynes’ original hypothesis retains some merit in describing the pattern of forward prices. Thus, it appears worthwhile to explore whether speculative pressure contributes to the forward rate anomaly. In fact, Carter *et al.* (1983) argued vehemently against omitting speculators from the standard CAPM. The structure of modern markets may limit the theory’s relevance.¹⁰ Those offering hedging services may recoup costs via bid-ask spreads. Today, we do not know the motives of other

traders as clearly as in Keynes’ world. However, the theory’s implications are matters worthy of research. As yet, the forward rate literature has left this interesting topic unexplored.

4. CONCLUSION

The forward rate anomaly has received its fair share of attention. However, a careful review of the literature revealed that the potential for speculators to impact on markets has been overlooked. Thus, results from future studies of this highly relevant topic should prove interesting.

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6. REFERENCES

- Baillie, R.T., Bollerslev, T., ‘Common Stochastic Trends in a System of Exchange Rates,’ *Journal of Finance*, 44, pp. 167-181, 1989.
- Baillie, R., Bollerslev, T., ‘A Multivariate Generalized ARCH Approach to Modelling Risk Premia in Forward Foreign Exchange Markets’, *Journal of International Money and Finance*, 9, pp. 309-324, 1990.
- Baillie, R., Bollerslev, T., ‘The Forward Premium Anomaly is Not as Bad as You Think’, *Journal of International Money and Finance*, 19, pp. 471-488, 2000.
- Barnhart, S.W., Szakmary, A.C., Testing the Unbiased Forward Rate Hypothesis: Evidence on Unit Roots, Co-Integration, and Stochastic Coefficients, *Journal of Financial and Quantitative Analysis*, 26, pp. 245-267, 1991.
- Bekaert, G., and Hodrick, R., ‘On Biases in the Measurement of Foreign Exchange Risk Premiums’, *Journal of International Money and Finance*, 12, pp. 115-138, 1993.
- Bessembinder, H., ‘Systematic Risk, Hedging Pressure and Risk Premiums in Futures Markets’, *Review of Financial Studies*, 5 (4), 1992, pp. 637-667 in Malliaris, A.G., *Handbook of Futures Market Volume One*, Edward Elgar, pp. 398-428, 1997.
- Bessembinder, H., Chan, K., ‘Time-Varying Risk Premia and Forecastable Returns in Futures Markets’, *Journal of Financial Economics*, 32, pp. 169-193, 1992.
- Bollerslev, T., ‘Generalised Autoregressive Conditional Heteroscedasticity’, *Journal of Econometrics*, 31, pp. 307-327, 1986.

⁹ Hull (2000, p. 74) addresses the relationship between expected spot and futures prices.

¹⁰ For example, the motive of traders is not common knowledge.

- Bollerslev, T., Engle, R.F., Wooldridge, J.M., 'A Capital Asset Pricing Model with Time-Varying Covariances', *Journal of Political Economy*, 96, pp 116-31, 1988.
- Brenner, R.J., Kroner, K.F., 'Arbitrage, Cointegration and Testing the Unbiasedness Hypothesis in Financial Markets', *Journal of Financial and Quantitative Analysis*, 30, pp. 23-42, 1995.
- Carter, C.A., Rausser, G.C., Schmitz, A., 'Efficient Asset Portfolios and the Theory of Normal Backwardation', *Journal of Political Economy*, 91, pp. 319-331, 1983.
- Cavaglia, S., Verschoor, W.F.C., Wolff, C.C.P., 'Further Evidence on Exchange Rate Expectations', *Journal of International Money and Finance*, 12, pp. 78-98, 1993.
- Chatrath, A., Lian, Y., Song, F., 'Commitment of Traders, Basis Behaviour, and the Issue of Risk Premia in Futures Markets', *Journal of Futures Markets*, 17, pp. 707-731, 1997.
- Cornell, W.B., Dietrich, J.K., 'The Efficiency of the Market for Foreign Exchange Under Floating Exchange Rates', *Review of Economics and Statistics*, 60, pp. 111-120, 1978.
- Cumby, R., 'Is it Risk? Explaining Deviations From Uncovered Interest Parity', *Journal of Monetary Economics*, 22, pp. 279-299, 1988.
- Domowitz, I., Hakkio, C.S., 'Conditional Variance and the Risk Premium in the Foreign Exchange Market', *Journal of International Economics*, 19, pp. 47-66, 1985.
- Engel, C.E., 'The Forward Discount Anomaly and the Risk Premium: A Survey of Recent Evidence', *Journal of Empirical Finance*, 3, pp. 123-92, 1996.
- Engle, R.F., 'Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation', *Econometrica*, 50, pp. 987-1007, 1982.
- Engle, R.F., Lilien, D.M., Robins, R.P., 'Estimating Time Varying Risk Premia in the Term Structure: The ARCH-M Model', *Econometrica*, 55, pp. 391-407, 1987.
- Fama, E.F., 'Forward and Spot Exchange Rates', *Journal of Monetary Economics*, 14, pp. 319-338, 1984.
- Ferson, W.E., Harvey, C.R., 'The Variation of Economic Risk Premiums', *Journal of Political Economy*, 99, pp. 385-415, 1991.
- Froot, K.A., Frankel, J.A., 'Forward Discount Bias: Is it an Exchange Risk Premium?', *Quarterly Journal of Economics*, 54, pp. 139-161, 1989.
- Harvey, C.R., 'The World Price of Covariance Risk', *Journal of Finance*, 46, pp. 111-157, 1991.
- Hodrick, R.J., 'International Asset Pricing with Time-Varying Risk Premia', *Journal of International Economics*, 11, pp. 573-587, 1981.
- Hull, J.C., 'Options, Futures & Other Derivatives', 4th Edition, Prentice Hall, 2000.
- Kaminsky, G., Peruga, R., 'Can a Time-Varying Risk Premium Explain Excess Returns in the Forward Market for Foreign Exchange?', *Journal of International Economics*, 28, pp. 47-70, 1990.
- Keynes, J.M., 'A Treatise on Money – Volume II', Macmillan, 1930.
- Kho, Bong-Chan, 'Time-Varying Risk Premia, Volatility, and Technical Trading Rule Profits: Evidence From Foreign Currency Futures Markets', *Journal of Financial Economics*, 41, pp. 249-290, 1996.
- Kolb, R.W., 'Is Normal Backwardation Normal?' *Journal of Futures Markets*, 12, pp. 75-91, 1992.
- Lintner, J., 'Security Prices, Risk, and Maximal Gains from Diversification', *Journal of Finance*, 19, pp. 587-615, 1965.
- Lucas, R.E., 'Interest Rates and Currency Prices in a Two-Country World', *Journal of Monetary Economics*, 10, pp. 335-360, 1982.
- McCurdy, T.H., Morgan, I.G., 'Tests for a Systematic Component in Deviations from UIP', *Review of Economic Studies*, 58, pp. 581-602, 1991.
- McCurdy, T.H., Morgan, I.G., 'Evidence of Risk Premium in Foreign Currency Futures Market', *The Review of Financial Studies*, 5 No 1 pp. 65-83, 1992.
- Mark, N.C., 'Time-Varying Beta and Risk Premia in the Pricing of Forward Foreign Exchange Contracts', *Journal of Financial Economics*, 22, pp. 335-354, 1988.
- Nieuwland, F.G.M.C., Verschoor W.F.C., Wolff C.C.P., 'Exchange Risk Premia in the European Monetary System', *Applied Financial Economics*, 10, pp. 351-360, 2000.
- Roll, R., Solnik, B., 'A Pure Foreign Exchange Asset Pricing Model', *Journal of International Economics*, 7, pp. 161-179, 1977.
- Sharpe, W.F., 'Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk', *Journal of Finance*, 19, pp. 425-442, 1964.
- Stulz, R., 'A Model of International Asset Pricing', *Journal of Financial Economics*, 9, pp. 383-406, 1981.
- Stulz, R., 'Does the Cost of Capital Differ Across Countries? An Agency Perspective', *European Financial Management*, 12, pp. 11-22, 1995.
- Zivot, E., 'Cointegration and Forward and Spot Exchange Rate Regressions', *Journal of International Money and Finance*, 19, pp. 785-812, 2000.