“Puzzles in Exchange Rate Economics: An Asset Allocation Perspective”

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Full Report of Research Activities and Results

Objectives and Methods

This research project aimed at shedding light on two major empirical puzzles in exchange rate economics that have not been explained even though these have been studied by a large body of research. The first is the failure of theoretical models of the exchange rate that link it to the economic fundamentals between countries like the money supply and domestic interest rates. It has been seen that the forecasts of the exchange rate using such models do no better than those generated using a naïve random walk model for the exchange rate. The second is the forward premium anomaly which is the tendency for high interest rate currencies to appreciate, when one might expect, instead, that investors would demand a higher interest rate on currencies expected to fall in value-the uncovered interest parity (UIP) condition.

Previous research has attempted to explain these anomalies by relying on statistical metrics to decide whether exchange rate models work, i.e. the criteria used to judge the success of models have been purely statistical. The novelty of our research is that we have examined these models using economic criteria, like the loss in utility. In other words, we have examined whether the predictions from these models could have been used by an investor to allocate assets and compare the performance of this asset allocation to that of an investor who believes that the models are incorrect. We find that, in the context of a simple asset allocation problem, the economic value of exchange rate forecasts from a fundamentals model can be greater than the economic value of random walk forecasts across a range of horizons.

We also provide evidence against the stylized fact that models based on economic fundamentals suggested by exchange rate determination theory are unable to produce accurate out-of-sample forecasts of the nominal exchange rate at short horizons (e.g. one quarter ahead). Using real-time data on a broad set of fundamentals for five major exchange rates over a sample spanning most of the recent float, we employ a predictive procedure that allows the relationship between exchange rates and fundamentals to evolve over time in a very general fashion. We find: (i) the well-documented weak out-of-sample predictive ability of the fundamentals is caused by poor performance of model-selection criteria, rather than lack of information content; (ii) the strength of the link between exchange rates and fundamentals is different across currencies; (iii) the difficulty of selecting the best predictive fundamentals model stems from the presence of frequent shifts in the parameters and the set of fundamentals driving exchange rates, reflecting swings in market expectations over time.
Furthermore, in our research we take seriously the fact that, in the context of managing exchange rate risk (both for investors and policy makers), interest centres on more than just point forecasts. This research provides a formal evaluation of recent empirical exchange rate models in terms of density forecasting performance. The economic value of the exchange rate density forecasts is investigated in the context of an application to a simple risk management exercise.

**Outputs and Results**

**Outputs**

The outputs of the project are as follows:


We now turn to a brief description of each of the papers and discuss our key results.

**Results**

**Output 1. Towards a Solution to the Puzzles in Exchange Rate Economics: Where Do We Stand?**

Exchange rate economics is characterized by a number of anomalies, or puzzles, which we struggle to explain on the basis of either sound economic theory or practical thinking. Put more simply, the international finance profession has not yet been able to produce theories and, as a consequence, empirical models which allow us to explain the behaviour of exchange rates with a reasonable degree of accuracy. This failure is witnessed by a variety of phenomena, and this paper analyses three specific ones.

The first puzzle analyzed is the “forward bias puzzle”, relating to the fact that the foreign exchange market is not only informationally inefficient, but it appears to be so inefficient that the forward market--capturing market expectations of future movements in exchange rates--may systematically predict future exchange rate movements in the
The second puzzle relates to the often documented lack of any strong tendency of exchange rates to move in sync with relative prices, which is what one would expect if purchasing power has to remain constant across countries over long periods of time in a world with international arbitrage in goods markets--this is usually termed the ‘purchasing power parity’ puzzle (Rogoff, 1996). The third puzzle, which in some respects encompasses the previous two, is the missing link between nominal exchange rates and the menu of economic or financial fundamentals that international economics theory suggests should drive exchange rates--this phenomenon is termed the “exchange rate disconnect” puzzle (Obstfeld and Rogoff, 2000). In essence, fundamentals appear to be unable to explain both the actual level of exchange rates--not only daily, but even monthly, quarterly and annually--and their volatility.

This paper summarizes the research relating to the above three puzzles in exchange rate economics--what we have learned, which aspects of the puzzles we have solved and which remain, and where further research progress is most likely to be made. While the paper will be of use to specialists in international finance and macroeconomics, given the importance of the relevant issues discussed in this article, essentially relating to understanding why exchange rates move the way they do, the assessment of the central questions motivating this analysis will be of interest to a wider audience of economists, policy makers and practitioners. This paper effectively defines the agenda of the research conducted in the project, which is devoted to shedding light on the above puzzles. The paper was written as the Keynote Speech at the 2004 Canadian Economics Association annual meetings, held in Toronto in June 2004.


In a highly influential paper, Meese and Rogoff (1983) noted that the out-of-sample forecasts of exchange rates produced by structural models based on fundamentals are no better than those obtained using a naive random walk or no-change model of the nominal exchange rate. These results, seen as devastating at the time, spurred a large literature that has re-examined the robustness of the Meese-Rogoff results, which represent an element of the “exchange rate disconnect puzzle”. Some recent research, using techniques that account for several cumbersome econometric problems, including small sample bias and near-integrated regressors in the predictive regressions, suggests that models based on monetary fundamentals can explain a small amount of the variation in exchange rates (e.g., Mark, 1995). However, others remain sceptical (e.g., Berkowitz and Giorgianni, 2001; Faust, Rogers and Wright, 2003). Thus, even with the benefit of almost twenty years of hindsight, the Meese-Rogoff results have not been convincingly overturned: evidence that exchange rate forecasts obtained using fundamentals models are better than forecasts from a naive random walk is still elusive (e.g., Neely and Sarno, 2002).

Prior research on the ability of monetary-fundamentals models to forecast exchange rates relies on statistical measures of forecast accuracy, like root mean squared errors. Surprisingly little attention has been directed, however, to assessing whether there is any economic value to exchange rate predictability (i.e., to using a model where the exchange rate is forecast using economic fundamentals). The present paper fills this gap. We investigate the ability of a monetary-fundamentals model to predict exchange rates by measuring the economic or utility-based value to an investor who relies on this model to allocate her wealth between two assets that are identical in all respects except the currency of denomination. We focus on two key questions. First, as a preliminary to
the forecasting exercise, we ask how exchange rate predictability affects optimal portfolio choice for investors with a range of horizons up to ten years. Second, and more importantly, we ask whether there is any additional economic value to a utility-maximizing investor who uses exchange rate forecasts from a monetary-fundamentals model relative to an investor who uses forecasts from a naive random walk model. We quantify the economic value of predictability in a Bayesian framework that allows us to account for uncertainty surrounding parameter estimates in the forecasting model. Indeed, parameter uncertainty or 'estimation risk' is likely to be of importance, especially over long horizons.

Our results with regard to the two questions addressed in this paper, obtained using three major US dollar exchange rates during the recent float and considering forecast horizons from 1 to 10 years, are as follows. First, we find that exchange rate predictability substantially affects, both quantitatively and qualitatively, the choice between domestic and foreign assets for all currencies and across different levels of risk aversion. Specifically, exchange rate predictability can generate optimal weights to the foreign asset that are substantially different (in magnitude and, sometimes, in sign) from the optimal weights generated under a random walk model.

Second, our main result is that we find evidence of economic value to exchange rate predictability across all exchange rates examined and for a wide range of plausible levels of risk aversion. In particular, the realized end-of-period wealth achieved by a US investor over a ten-year horizon using a monetary fundamentals-exchange rate model for forecasting the exchange rate is higher than the corresponding end-of-period wealth obtained by an investor who acts as if the exchange rate were a random walk. Our results show that the economic value of predictability can be substantial also over relatively short horizons and across different levels of risk aversion. We view our findings as suggesting that the case against the predictive power of monetary fundamentals may be overstated.


Exchange rate risk plays a major role in international portfolio diversification and in several aspects of economic policy, including the assessment of the uncertainty surrounding prices of exports and imports, the value of international reserves and open positions in foreign currency, and the domestic currency value of debt payments and workers' remittances which, in turn, may affect domestic wages, prices, output and employment. In international financial markets, expectations of future exchange rates affect agents' decisions in a number of respects, including their investment, hedging, and borrowing and lending decisions. It is not surprising, therefore, that an enormous empirical literature has developed which focuses on modelling and forecasting nominal exchange rates.

While macroeconomic fundamentals do not appear to be useful in forecasting exchange rates when used in standard time series models, however, models which exploit the information in the term structure of forward exchange rates and forward premia have produced satisfactory results. Clarida and Taylor (1997) first argued that, although the forward exchange rate is not an optimal predictor of the future spot exchange rate, forward rates may still contain valuable information for forecasting future spot exchange rates. Clarida and Taylor (1997) use a linear vector equilibrium correction model (VECM) of spot and forward exchange rates and show that is possible to extract sufficient information from the term structure of forward premia to outperform the
random walk model for several exchange rates in out-of-sample forecasting. Then, Clarida, Sarno, Taylor and Valente (2003) generalize the linear VECM of spot and forward exchange rates to a nonlinear, three-regime Markov-switching VECM (MS-VECM) which is found to outperform a random walk as well as to improve on the linear VECM in terms of out-of-sample forecasting.

An extensive body of literature has investigated the performance of exchange rate models in forecasting the level of the exchange rate. However, surprisingly little attention has been devoted to forecasting the density of exchange rates. In a decision-theoretical context, the need to consider the density forecast of a variable - as opposed to considering only its conditional mean and variance - seems fairly accepted on the basis of the argument that economic agents may have loss functions that do not depend symmetrically on the realizations of future values of potentially non-Gaussian variables (Granger, 2003). In this case, agents are interested in forecasting not only the mean and variance of the variables in question, but their full predictive densities. In various contexts in economics and finance - among which the recent boom in financial risk management is an obvious case - there is strong need to evaluate density forecasts.

Our research contributes to the relevant literature in that we re-examine the forecasting performance of term structure models of exchange rates, which were shown to outperform a random walk in out-of-sample point forecasting by Clarida and Taylor (1997) and Clarida et al. (2003). However, we assess the ability of these models to forecast out-of-sample the one-step-ahead density of nominal exchange rates, hence filling, to some extent, the important gap in the literature described above. Our analysis is carried out using the recent techniques on evaluating density forecasts mentioned above as well as on Value-at-Risk (VaR) calculations.

In particular, using weekly data for eight bilateral dollar exchange rates from January 1985 to December 2003, we focus on the ability of both the linear VECM and the MS-VECM to forecast the one-week-ahead exchange rate density. We find that Markov-switching term structure models of exchange rates produce satisfactory density forecasts of exchange rates. In particular, the MS-VECM of the term structure convincingly outperforms a random walk forecast and a linear term structure VECM in our density forecasting exercise, suggesting that the allowance for nonlinearity in these models may be particularly important to produce satisfactory out-of-sample density forecasting performance.

Finally, we illustrate the practical importance of our results on density forecasting with a simple application to a risk management exercise. In recent years, trading accounts at large financial institutions have shown a dramatic growth and become increasingly more complex. Partly in response to this trend, major trading institutions have developed risk measurement models designed to manage risk. The most common approach employed in this context is based on the VaR methodology, where VaR is defined as the expected maximum loss over a target horizon within a given confidence interval - more formally, VaR is an interval forecast, typically a one-sided 95% or 99% interval of the distribution of expected wealth or returns. In our simple application we analyze the out-of-sample forecasting performance of term structure models of exchange rates, investigating the implications of these forecasts for a risk manager who has to quantify the risk associated with holding a currency portfolio over a one-week horizon. This application further illustrates how the MS-VECM captures satisfactorily the higher moments of the predictive density of exchange rates, generating VaRs that estimate the probability of large losses better than the other two competing models. Put another way, our findings indicate that better density forecasts of exchange rates, of the type recorded by the regime-switching model considered in this paper, can potentially lead to
substantial improvements in risk management and, more precisely, to better estimates of downside risk.

Output 4. **The Forward Bias Puzzle and Nonlinearity in Deviations from Uncovered Interest Parity: A New Perspective**

In a highly influential paper, Fama (1984) noted that high interest rate currencies tend to appreciate, whereas one might suppose that investors would demand higher interest rates on currencies expected to fall in value. In turn, this result suggests that the forward premium tends to be inversely related to future exchange rate changes, in contrast to the UIP hypothesis. This anomaly, often termed the “forward bias puzzle,” continues to spur a large literature. However, regardless of the increasing sophistication of the econometric techniques employed and of the increasing quality of the data sets utilized, researchers generally report results which reject UIP. In fact, for the major floating currencies against the dollar, the spot exchange rate has usually been recorded to fall when the forward market would have predicted it to rise and vice versa (Sarno and Taylor, 2003; Ch. 2, and the references therein). Attempts to explain, statistically and economically, the forward bias puzzle have met with limited and mixed success, especially for plausible degrees of risk aversion (e.g. Lewis, 1995).

In this paper we start from noting that prior empirical research in this area has generally relied on linear frameworks in analyzing the properties of UIP deviations. This is surprising since several authors have argued that the relationship between expected exchange rates and interest rate differentials may be nonlinear for a variety of reasons, including transactions costs (see, inter alia, Baldwin, 1990; Dumas, 1992; Hollifield and Uppal, 1995; Sereu and Wu, 2000), central bank intervention (e.g. Mark and Moh, 2002; Moh, 2002), and the existence of limits to speculation (e.g. Lyons, 2001, pp. 206-220). In particular, the limits to speculation hypothesis is based on the idea that financial institutions only take up a currency trading strategy if this strategy is expected to yield an excess return per unit of risk (or a Sharpe ratio) that is higher than the one implied by alternative trading strategies, such as, for example, a simple buy-and-hold equity strategy. This argument effectively defines a band of inaction where the forward bias does not attract speculative capital and, therefore, does not imply any glaring profitable opportunity and will persist until it generates Sharpe ratios that are large enough to attract speculative capital away from alternative trading strategies (Lyons, 2001).

Although the literature has already documented that normal values of the forward premium may impact on future exchange rates differently from extreme values (e.g. Bilson, 1981; Flood and Rose, 1994; Flood and Taylor, 1996; Huisman, Koedijk, Kool and Nissen, 1998) and some authors have investigated the role of nonlinearities in the term structure of forward premia for exchange rate forecasting (e.g. Clarida, Sarno, Taylor and Valente, 2003), the potential importance of nonlinearities to shed light on the forward bias puzzle remains largely under-researched. The present paper fills this gap. Our empirical framework provides a characterization of the UIP condition which allows us to test some of the general predictions of the limits to speculation hypothesis and to assess its potential to explain the forward bias puzzle and the excess returns predictability documented in the literature.

Our empirical results, obtained using five major US dollar exchange rates and considering forward rates with 1- and 3-month maturity, are as follows. First, there is strong evidence that the relationship between spot and forward exchange rates is characterized by significant nonlinearities. While the detection of nonlinearities in this context is not novel per se, our empirical model proves especially useful for
understanding the properties of deviations from UIP. In particular, consistent with the
limits-to-speculation hypothesis which we use to motivate our nonlinear spot-forward
regression, we find that, when Sharpe ratios are small, departures from market efficiency
and hence the forward bias are statistically significant and persistent but economically too
small to attract speculative capital, while when Sharpe ratios are large enough to attract
speculative capital the spot-forward relationship reverts rapidly towards the UIP
condition.

Second, in a battery of Monte Carlo experiments we demonstrate that, if the true
data generating process (DGP) governing the relationship between spot and forward
exchange rates were of the nonlinear form we consider in this paper, we can replicate the
empirical results generally reported in the literature. In particular, estimation of the
conventional linear spot-forward regressions would lead us to reject the validity of UIP
with parameters estimates that are very close to the ones observed using actual data.
However, the failure of UIP and the finding of a forward bias is a feature that the DGP
has only in the inner regime, which is the regime where expected deviations from UIP
are tiny enough to be economically unimportant and unlikely to attract speculative
capital.

Our interpretation of the empirical and Monte Carlo evidence in this paper is that
the stylized fact that the UIP condition is statistically rejected by the data is not indicative
of substantial market inefficiencies. Indeed, the inefficiencies implied by this rejection
appear to be tiny and it is not clear, on the basis of the evidence in this paper, that they
are economically important.

Output 5. Exchange Rates and Fundamentals: Footloose or Evolving
Relationship?

Prior research has documented that economic fundamentals do not contain information
useful for forecasting exchange rates partly because the behaviour of the “virtual
fundamentals,” that is the fundamentals that would be capable of explaining the variation
in foreign exchange rates, is radically different from the behaviour of the fundamentals
suggested by exchange rate determination theory (e.g. Flood and Rose, 1995; Baxter and
Stockman, 1989). This evidence may be seen as suggesting that there are speculative
forces at work in the foreign exchange market which are not reflected in the usual menu
of economic fundamentals.

Notwithstanding this evidence, it is hard to believe that broad knowledge of the
state of the economy at a certain point in time is useless information to forecast how
exchange rates may move in the future. It may be that exchange rate models perform
poorly not (only) because the information in the fundamentals is deficient, but because
volatile expectations or departures from rationality are likely to account for the failure of
exchange rate models. For example, Frankel (1999) argues that exchange rates are
detached from fundamentals because of swings in expectations about future values of the
exchange rate, listing several pieces of evidence suggesting that expectations are to blame
for such behaviour. In this line of reasoning, recently Bacchetta and van Wincoop (2004)
have provided a theory of exchange rate determination which incorporates the fact that
practitioners in the foreign exchange market regularly change the weight they attach to
different economic variables – as evidenced in a variety of survey studies (e.g. Cheung
and Chinn, 2001) – in the context of a stylized rational-expectations exchange rate
determination model. This model is capable of rationalizing parameter instability on
empirical exchange rate models – often documented in the relevant literature (e.g. Rossi,
2004, 2005) – in terms of a “scapegoat” story, where some variable is given excessive
weight during some period, implying movements in the exchange rate that are unrelated with observed economic fundamentals, for example due to unobserved liquidity trades. As the market rationally searches for an explanation for the observed exchange rate change, it may attribute it to some macroeconomic indicator, which in turn becomes the scapegoat and influences trading strategies. Over time different observed variables may be taken as scapegoat, so that the weights attributed to economic variables change.

Surprisingly little attention has been directed by the empirical literature, however, towards assessing whether the potential of these considerations for establishing an economically meaningful relationship between exchange rates and fundamentals. Our paper fills this gap. We build an empirical framework that explicitly takes into account the survey evidence that there are changing weights in fundamentals and that no model of fundamentals appears to perform well for long periods of time. Our framework allows for a menu of fundamentals that comprises not only the standard monetary fundamentals most commonly used in the literature, but also other variables suggested by exchange rate determination theory, including net foreign assets, interest rates, the trade balance, and lagged values of exchange rate changes. We employ a recursive procedure where we select, quarter by quarter, the best model on the basis of a variety of statistical and economic criteria within all possible combinations of fundamentals, allowing for the fundamentals model and the parameters to change at each point in time. We perform an out-of-sample forecasting exercise using real time data for the fundamentals, for each criterion used in the model selection procedure and for several major dollar exchange rates. We compare the results of this purely out-of-sample exercise with the results that would have been obtained if one knew the best performing model. This comparison sheds light on the usefulness of the information embedded in the fundamentals for forecasting the exchange rate as well as on the ability of the model selection procedure to use such information optimally.

We focus on two key questions. First, as a preliminary to the forecasting exercise, we perform a virtual search for the best performing exchange rate model given a broad set of fundamentals available in real time over the recent float for our dollar exchange rates. In other words, we ask whether, allowing for shifts in the weights attached to the fundamentals over time, the best model that optimizes such information is indeed capable of predicting the exchange rate with a reasonable degree of accuracy. Second, when the previous exercise suggests that there is a (time-variant) fundamentals model capable of explaining and predicting exchange rate movements, we ask whether it is possible to recover the best model obtained earlier when the out-of-sample forecasting exercise is conducted using conventional model selection criteria to select the best exchange rate model, period by period, over our sample.

Our results, obtained using five major US dollar exchange rates during the recent float and considering exclusively short-term forecasts of one-quarter ahead, are as follows. First, the information embedded in the economic fundamentals, when used in a framework that allows for the set of fundamentals in the model change over time and for parameter instability, can explain future exchange rate movements with a remarkable degree of accuracy for some currencies. However, this requires the ability to select the best model from the various set of models that can be used on the basis of information available, i.e. this requires that the investor must have available a reliable model selection criterion to discriminate among different specifications of the fundamentals model. Second, if conventional (statistical and/or economic) model selection criteria are used to choose ex ante the best model from a large pool of models available, the same set of economic fundamentals is not useful in forecasting exchange rates out of sample. This finding is largely due to the inability to model selection criteria to identify the predictive
variables to be used ex ante and to capture the frequent shifts in the best model capturing the evolving dynamic relationship between exchange rates and fundamentals.

We show that models that optimally use the information in the fundamentals change often and this implies frequent shifts in the parameters. Our interpretation of these results is that standard model selection criteria appear to be unable to generate such shifts, yielding empirical exchange rate models that cannot forecast the exchange rate better than a random walk model. Therefore, while the stylized fact that fundamentals models cannot beat a no-change model is--yet again--confirmed in this paper, the reason for this result is, on the basis of the evidence presented here, different from many other studies. Our evidence suggests that the exchange rate disconnect phenomenon is unlikely to be caused by lack of information in the fundamentals, and more likely to be the result of poor model selection criteria in this context.
Activities

Conference presentations:
- Presenter: Lucio Sarno: Canadian Economics Association Annual Conference (Keynote Speaker), Toronto, June 2004.

Seminar presentations:
- Presenter: Lucio Sarno: International Monetary Fund, Washington DC (July 2004); European Central Bank, Frankfurt (October 2004), Central Bank of Norway, Oslo (February 2005), University of Kent (January 2005), Catholic University of Leuven (February 2005).
- Presenter: Giorgio Valente: University of Exeter (November 2005); University of Hong Kong (April 2005).
- Presenter: Abhay Abhyankar: University of Edinburgh (November, 2005), University of Bristol (April 2005).

Impacts

These research results have not been used or applied outside of the project; hence there has been no commercial exploitation, either actual or proposed.

Further Research Priorities

The issues researched in this project remain important in the academic and policy making circles and there are a number of directions in which they may be extended. This applies to each of the three issues we analysed in this research project. For example, it would be interesting to further analyse the exchange rate disconnect puzzle in the context of an very realistic asset allocation perspective where investors consider exchange rate models as an element of their more general models used to allocate their wealth across a broad set of assets, including equities and bonds. It would be equally interesting to focus on the implications of our predictability results on other utility optimization problems, such as that of an optimizing central bank of a small open economy with an inflation target. Although we believe our contributions have added novel results to the literature on exchange rate behaviour, a lot remains to be done to achieve consensus on the fundamental questions addressed in this line of research. Each of the researchers involved in this research project remains committed to this research agenda.