Research Proposal:

Exchange rates and interest rates: can term structure models explain currency movement? An investigation of the euro dollar exchange rate since 1999.

Provisional title of your research article.

Exchange rates and interest rates: can term structure models explain currency movement? An investigation of the euro dollar exchange rate since 1999.

The specific research question(s) to be addressed or hypothesis(es) to be tested.

Traditionally macroeconomic models have been used to try to explain currency movements. However, none of these models has been able to outperform the random walk model. Also, much literature suggests that forward rates are not an optimal predictor of the spot rate.

Recent research in the area of currency movements and forecast models has looked at whether the information contained in the term structure can be used to forecast currency moves and whether the results of these models outperform the macroeconomic models and more importantly the random walk model. The most promising research to date has been the research by Clarida, Sarno, Taylor and Valente, (2003). The model used in this study allowed for nonlinearities in exchange rate movements and claims to 'significantly outperform both random walk and, to a lesser extent, a liner term-structure vector equilibrium correction model for four major dollar rates across a range of horizons'.[1] For my investigation on the movements in the euro dollar exchange rate I will attempt to model the euro-dollar exchange rate since 1999 using a similar nonlinear term structure model. To the best of my knowledge there is no significant literature on modeling this exchange rate using a nonlinear model like I propose.

[1]Clarida, Sarno, Taylor, and Valente. "The out-of-sample success of term structure models as exchange rate predictors: a step beyond". Journal of International Economics, Volume 60, Issue 1, May 2003. Page 61

The relationship of the proposed study to previous research.

There is much theory on what determines movements in currencies, particularly for small open economies that have free trade. Perhaps the best known model of currency movements is the Purchasing Power Parity model (PPP). This model is based on the 'law of one price' (LOOP). It states that 'if domestic tradable goods are perfect substitutes for foreign goods and the goods market is 'efficient', then 'middlemen' or arbitrageurs will act to ensure that the price is equalised in a common currency'.[2] PPP can be broken down further into absolute PPP and relative PPP. The absolute model assumes that the price in each country is the same while the relative model does not assume that the price is the same but that prices move proportionately.

However, there are many problems with PPP as an exchange rate model. Krugman, 1978, found that some goods sold to foreign markets are set to the local price and as a result are immune to price changes. Knetter, (1989, 1993) also found support for this pricing to market – PTM – especially for German and Japanese firms.

Another issue with PPP is that it is hard to determine what exactly can be classified as similar goods. Even if the same good is available in two places for different prices, the arbitrage argument assumes that there are no costs associated with sourcing the good from the cheaper location. This is obviously not a realistic assumption.

Engel and Rogers (1996) found that prices are not equalised across countries. They researched 14 price indices for 23 cities in the United States and Canada and found that:

1. the relative price of the same goods between two cities within one country is a positive function of the distance between the two cities.

[2] Cuthbertson and Nitzsche. Quantative Financial Economics. Second edition. Page 553.

2. the 'border effect' increases the size of the price difference.
3. cross-border price differences are more persistent than those within countries.

Covered interest rate parity (CIP) and uncovered interest rate parity (UIP) concentrate on the relationship between the current spot fx rate and the forward fx rate. CIP says that the forward rate is given by:

$F_t = s_t(1 + r_t)/(1 + r*_t)$ where:

F_t is the forward rate,

S_t is the spot rate

r_t is the domestic interest rate

$r*_t$ is the foreign interest rate.

UIP implies that the expected rate of depreciation of the domestic currency equals the interest differential between the domestic and foreign country[3].

If CIP and UIP hold together, then the forward rate is an unbiased predictor of the future spot rate.

However, tests of standard empirical exchange rate models and forward rate unbiasedness (FRU) do not support the theory. Meese and Rogoff, 1983 found that standard empirical exchange rate models could not outperform the random walk forecast model.

Also, Hensen and Hodrick, 1980; Frankel, 1980 and Bilson, 1981, all found that the forward rate is not an optimal predictor of future spot rates or that the forward premium is not an optimal predictor of the rate of depreciation[4].

[3] Cuthbertson and Nitzsche. Quantative Financial Economics. Second edition. Page 563.

Many multi factor macroeconomic models have extended the basic assumptions of PPP and attempted to model movements using multiple macroeconomic variables. These have also had little success when tested against the random walk model. Attempts to explain the failure of the these models have not proved successful and as a result the random walk model of exchange rate movements remains the standard comparator for exchange rate models.

More recent literature has focused on the relationship between term structures and exchange rates. Clarida and Taylor (1997) argued that the failure of the forward rate to optimally predict the future spot rate did not mean that there was not valuable information in the term structure of forward rates. They established a linear vector equilibrium correction model (VECM) for spot and forward exchange rates. This allowed them to abstract sufficient information from the term structure of forward rates to outperform the random walk forecast. In fact, at the one year forecasting horizon, their improvement over the naïve random walk model is of the order of 40% in terms of root mean squares[5].

A less successful term structure model was suggested by Inci and Lu in their paper entitled 'Exchange rates and interest rates: can term structure models explain currency movements?'. They constructed an international term structure model that has excellent

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[4] Clarida, Sarno, Taylor, and Valente. "The out-of-sample success of term structure models as exchange rate predictors: a step beyond". Journal of International Economics, Volume 60, Issue 1, May 2003. Page 62

[5]Clarida, Sarno, Taylor, and Valente. "The out-of-sample success of term structure models as exchange rate predictors: a step beyond". Journal of International Economics, Volume 60, Issue 1, May 2003. Page 73

empirical performance in tracking movements in exchange rates and currency returns[6]. However, this model failed to outperform the random walk model and the authors concluded that the information contained in the term structure was not sufficient on it's own to explain changes in exchange rates.

Another set of literature has focused on whether exchange rate movements are linear. There is strong evidence to suggest that there are in fact nonlinearities in exchange rate movements. Various macroeconomic non-linear exchange rate models have been suggested. However, while these models have had satisfactory results, they have not managed to outperform the random walk model. Examples of these models are those presented by Diebold and Nason, 1990; Engel, 1994; Meese and Rose, 1990; and Meese and Rose, 1991.

Clarida, Sarno, Taylor and Valente, (2003), took the earlier term structure model suggested by Clarida and Taylor and the findings in the literature on nonlinearities in exchange rate movements and investigated whether allowing for nonlinearities in the underlying data-generating process for the term structure yielded superior exchange rate forecasts. They used a three-regime Markov-switching vector equilibrium correction model for the spot rate and the term structure of forward rates. Their model outperformed the random walk model and also a linear term structure vector equilibrium correction model. They looked at four major USD exchange rates, namely dollar-franc, dollar-mark, dollar-yen and dollar-sterling.

[6]Inci and Lu. "Exchange rates and interest rates: can term structure models explain currency moves?" Journal of economic Dynamics and Control, Volume 28, Issue 8, June 2004. Page 1595

The success of their model at forecasting currency moves is the reason I chose to use a nonlinear term structure model to investigate whether the movements in the euro dollar exchange rate since 1999 can be modelled with the same success.

The rationale for doing this research.

Since the introduction of the Euro in 1999, the euro-dollar exchange rate has been extremely volatile falling to a low of nearly $.82 before rising to a rate of above $1.36. However, despite the currency pair's volatility and its apparent disregard for fundamentals, I cannot find any significant literate on the success of existing models at forecasting the moves seen over the past six years.

The first contribution I hope to make to the literature with my research is to add an analysis of the euro dollar exchange rate that will hopefully go some way towards filling this gap. Secondly, I hope to add to the existing literature on the success of using nonlinear term structure models to forecast exchange rate movements. To date the research has yielded very positive results and further support for this method of modelling exchange rate movements would add weight to the findings of the previous research. I will test the results of my model against the random walk model to see whether the superior results found in previous studies of this nature can be replicated. This could potentially be a step towards shifting the focus of exchange rate models from macroeconomic factors alone to either incorporating term structures or looking at them in isolation as predictors of currency moves.

Also, as part of my research, I intend to compare the behaviour of the euro-dollar exchange rate to the behaviour of the dollar-mark exchange rate. I will attempt to model the dollar mark rate using the same model that I will use on the euro dollar exchange rate. As the closest currency to the euro, one would expect that the model I use should have similar results for the euro-dollar test as it does for a dollar-mark test and that the behaviour of the two exchange rates would be similar. Significant differences would imply that the fundamentals of exchange rate movements in the eurozone have changed since the introduction of the single currency.

The sources of data to be used.

Clarida, Sarno, Taylor and Valente tested their model using weekly observations of spot, 4, 13, 26 and 52 week forward USD exchange rates against the mark for the period January 7 1979 to December 31 1998. The estimations were carried out over the period January 1979 to December 1995 and the last 3 years were used for out-of-sample testing. I will look at the same data for the euro-dollar exchange rate for the period 1999 to 2006. Given the relatively short sample period compared to that used in previous studies, I will use daily data to increase the sample size. This data is easily available from either Bloomberg or Reuters.

The proposed methods for doing the research.

I will attempt to model movements in the euro dollar exchange rate using a term structure model that takes account of nonlinearities in exchange rate movements. The approach I use will be similar to that used by Clarida, Sarno, Taylor and Valente, (2003). However, I

will attempt to model the nonlinearities using a different approach than they used in their research.

Clarida, Sarno, Taylor and Valente, (2003), used a regime-switching vector equilibrium correction model to investigate whether allowing for nonlinearities in the data generating process of their term structure model produced superior results to the random walk model.

They broke the spot exchange rate down into two parts, a unit root process (mt) which evolved as a random walk with drift and qt, which is a stationary process with a mean of zero and a finite variance.

$$s_t = m_t + q_t \tag{1}$$

If the risk-neutral efficient market hypothesis holds, the spot rate should fully reflect all the available information at t, Ω_t and the forward rate should optimally predict the future spot rate. However, there is very little literature to support the RNEMH. In fact, there is a large amount of literature that rejects the hypothesis. Clarida and Taylor (1997) defined the deviation from the RNEMH as:

$$\gamma_t \equiv f_t^{h(k)} - E(s_{t+h(k)} | \Omega_t) \tag{2}$$

Combining (1) and (2), they came up with an expression for the forward rate,

$$f_t^{h(k)} = \gamma_t + h(k)\Theta + E_t(q_{t+h(k)} | \Omega t) + m_t \tag{3}$$

and an expression for the forward premium at time t,

$$f_t^{h(k)} - s_t = \gamma_t + h(k)\Theta + E_t(q_{t+h(k)} - q_t | \Omega_t) \tag{4}$$

Where Θ is the drift of the random walk process m_t.

Equation (4) tells us that if the deviation from the RNEMH is stationary, then the forward premium must also be stationary. This implies that forward and spot rates exhibit a common stochastic trend and are cointegrated with cointegration vector [1,-1]. Since this is true for any *h(k)*, if we consider the vector of forward rates of tenor h (1) to h(m) periods, together with the current spot rates, $[s_t, f_t^{h(1)}, f_t^{h(2)}, ..., f_t^{h(m)}]$, then this must be cointegrated with m unique cointegrating vectors, each given by a row of the matrix $[-i, I_m]$, where I_m is an m-dimensional identity matrix and I is an m-dimensional column vector of ones[7].

They also state that given the granger Representation Theorem (Engle and Granger, 1987) the same set of spot rates have a VECM (vector equilibrium correction model) representation in which the term structure of forward premia play the part of the equilibrium errors. Clarida and Taylor use this framework to show that a large amount of information can be extracted from the term structure to forecast spot rates, even though the forward rate is not an optimal predictor of the future spot rate.

Clarida, Sarno, Taylor and Valente (2003) expand this model and to allow for nonlinearities by using a Markov-switching regime framework to model regime shifts in the dynamic relationship between spot exchange rates and the term structure of forward rates. The procedure they use is an extension of Hamilton, 1988 and Hamilton, 1989, and allows them to apply it to cointegrated vector autoregressive (VAR) and VECM systems.

[7] Clarida, Sarno, Taylor, and Valente. "The out-of-sample success of term structure models as exchange rate predictors: a step beyond". Journal of International Economics, Volume 60, Issue 1, May 2003. Page 64

I will attempt to allow for nonlinearities in my model using a variant of the STAR model. The general specification of the STAR model takes the following form:

$$y_t = \alpha_0 + \sum \alpha_i y_{t-i} + (\alpha_0^* + \sum \alpha_i^* y_{t-i}) F(y_{t-d}) + \varepsilon_t$$

where:

y_t is a stationary variable such as a change in the exchange rate or an adjustment from the equilibrium from my linear regression

$\alpha_i (i = 1,....., p)$ is the linear autoregressive parameter

α_0^* is the nonlinear intercept term

$\alpha_i^* (i = 1,....., p)$ is the nonlinear autoregressive parameter

$f(y_{t-d})$ is the transition function which characterises the smooth transition between two regimes

y_{t-d} is a lag of the independent variable or can be any variable that proves significant in explaining changes in the exchange rate and

ε_t is the white noise residual with zero mean and constant variance.

There are two main variations of the STAR model which differ by the specification of the transition function. There are LSTAR and ESTAR.

LSTAR has a logistic transition function while ESTAR has an exponential specification.

I have not found any literature that uses the LSTAR model to investigate movements in currencies. However, the ESTAR model has been used in many previous attempts to model movements in currencies.

Ozaki (1985) captured the adjustment mechanism implied by previous research such as transaction costs or transport costs using an ESTAR model.

Rogoff (1996) used an ESTAR model to show that "whilst the speed of adjustment for small shocks around equilibrium will be highly persistent, larger shock mean revert much faster than the "glacial rates" previously reported for linear models".[8]

Paya and Peel (2005) found further evidence in support of the ESTAR nonlinear model with a shifting equilibrium as a forecaster of movements in their analysis of the real dollar-sterling exchange rate.

Given the success of these previous studies I expect that I will also find the ESTAR model more useful for my research than the LSTAR model.

I will begin by trying to determine a good linear model specification based on the relationship between the term structure of interest rates and currency movements. I will then test this model for evidence of nonlinearities, particularly an ESTAR relationship. If I find evidence of a nonlinear ESTAR relationship, I will attempt to specify an appropriate ESTAR model. This will involve implementing the ESTAR model using the variables identified in my linear investigation using nonlinear least squares. Arriving at my final specification will involve including and omitting various combinations of variables so that the optimal results are achieved by the model.

[8] Ivan Paya and David A Peel. "A new analysis of the determinants of Real Dollar-Sterling Exchange Rate: 1871-1994". Working paper 2005.

Finally I will test the results of my model against the random walk model to see whether it produces superior results.

Plan for research.

The initial research for this research will require a full examination of the literature on exchange rate theory and models. There is too much literature on this topic to research it all so the main challenge for my literature review will be narrowing down the literature to that which is most relevant for my research.

Literature on macroeconomic models suggests that no model has been proposed that consistently outperforms the random walk model. While I will include a section on these models in my literature review, my main focus will be on the random walk model and any literature available on the relationship between term structures and the forecasting of exchange rates.

While there is a lot of literature on exchange rate models in general, from my initial investigations, there does not seem to be much literature on term structure models as predictors of currency moves. While this may be limiting, it also presents the opportunity to add something new and useful to the existing literature.

I expect that the biggest challenge of this research will be developing the technical skill needed to apply the nonlinear model I intend to use. To properly apply this model I will need to ensure that I have a good understanding of vector autoregressive models (VAR), error correction models, cointegration and unit roots, and threshold models. It is in this

area that I expect to need the most assistance and advice from someone with a better understanding of these models and how they are applied.

The data I will be using is daily observations of spot, 4, 13, 26 and 52 week forward USD exchange rates against the euro. This information is easily available in both Reuters and Bloomberg. I have access to both systems so sourcing the data will not be a problem.

I intend to begin my literature review in March 2006. I have already identified many of the articles I intend to include in my literature review so I expect that I will have this review done by the end of March 2006. I will submit the literature review for initial comments at this stage.

Once I have completed the literature review, I intend to study the various models I will need to use to research this research. As I have used these models before it is hard to estimate how long this will take. However, as most of them are extensions of simpler models that I have used before, I expect that I should have this covered by the start of April 2006. At this stage I hope to have the first draft of the literature review.

The final phase of my research will be to run the regressions on my data and investigate the performance of this model of exchange rate movements both on an absolute level and relative to other models, particularly the random walk model. This will provide me with the information to write up my findings and conclusions. The work I have done on the regression techniques required to test this model should mean that running the regressions

to test this model will not take more than three weeks. I will start to write up my findings and conclusions in June. I expect that it will take 2 weeks to interpret my results and write them up. I intend to have the first draft of my research paper is ready for submission by mid June. This will give me sufficient time to redraft and refine the research paper before the final submission date.

Preliminary Bibliography:

Clarida, Sarno, Taylor, and Valente. “The out-of-sample success of term structure models as exchange rate predictors: a step beyond”. Journal of International Economics, Volume 60, Issue 1, May 2003. Pages 61-83

Inci and Lu. “Exchange rates and interest rates: can term structure models explain currency moves?” Journal of economic Dynamics and Control, Volume 28, Issue 8, June 2004. Pages 1595-1624

Ivan Paya and David A Peel. “A new analysis of the determinants of Real Dollar-Sterling Exchange Rate: 1871-1994”. Working paper 2005.

Keith Cuthbertson, Dirk Nitzsche. Quantative Financial Economics, Second edition.

Chris Brooks. Introductory econometrics for finance.

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