The Out-of-Sample failure of Empirical Exchange Rate Models –A Cointegration perspective.

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Abstract

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1 Introduction

Many approaches tried to model FX-rates since the start of a free-floating system after Bretton Woods in the 1970s. Monetary models, linking macroeconomics variables to FX-rates, were the first to emerge and due to their compelling theoretical intuition soon became the reference in the field. The enthusiasm for such elegant models was nonetheless soon diminished by two seminal works. Meese and Rogoff (1983a, [1]) and Meese and Rogoff (1983b [2]) demonstrated how no one of the different monetary models could beat a random walk without a drift in modeling FX-rates out of sample. After the evidence was presented the opinion divided. Some argued for a sample issue and confined the problem to the specific historical period, some argued for the limit of the linear models used by the authors to approach monetary models, some argued for a fail of monetary models and their underlying assumptions and finally some started to approach the issue in an innovative way turning their interest towards micro-based models aiming to capture the complexity of market information asymmetries and investors heterogeneity among the others [1]

While all such different reactions contributed to a further understanding of FX-rates properties we question whether the runaway from linear monetary models is justified given the methodological approach presented in the studies of Meese and Rogoff and the lack of a cointegration analysis later formalized by Granger and Engle (1987, [4]). Given the gap in academic literature exploring this cointegration relationship our study will propose a study of it at monthly lag. This methodological study stands therefore as a revision of the out of sample failure of foreign exchange rates testing whether macroeconomics variables are indeed incapable of explaining FX-rates movements before exploring more nuanced fields such as nonlinear and micro-based modeling. The hope is therefore to avoid over engineering and over complication of the issue going back at the fundamentals providing market makers and policy makers a simple framework to work with.

In the specific, our study aims at exploring the above at a monthly lag frequency on a self developed data set for the recent period ranging from 1986 to 2007. Such period will allow a consistent estimation of all of the necessary parameters given the models of choice, moreover it will avoid to model the most recent financial crises where structural breaks in the series arise. As in Meese and Rogoff (1983a and 1983b, [1, 2]) we are going to explore the out of sample forecasting of foreign exchange rates for three major monetary models. Firstly, the monetary models first presented by Frenkel (1976, [5]) and Mussa (1976, [6]) claiming for a link among monetary mass differentials, interest rates differentials output gap and FX-rates. Secondly the sticky price model where inflation rates differential plays a crucial role as prices adjusts sluggish to macroeconomics shocks affecting FX-rates (Dornbush 1976, [7]). Finally, a portfolio balance model claiming for the importance of monetary flows and net current account differentials as a key determinant for FX-rates changes as in Hooper and Morton (1982, [8]).

[1]See Balliu and King (2005, [3]) for a general survey.

Based on such monetary models five different models will be analyzed in order to forecast FX-rates. Three of them are presented in the seminal work of Meese and Rogoff (1983a, [1]) and will pose the benchmark to check whether the result of the paper hold in the time frame of interest. These are a simple random walk forecast, an OLS estimation without inclusion of lagged terms and a vector autoregressive model. On the top of it we will analyze the performance of transfer models discussed in Montgomery and Weatherby (1980, [9]) and the vector error correction model representation of the cointegration relationship between macroeconomics variables and FX-rates proposed by Granger and Engle (1987, [4]).

2 Dataset

The dataset, comprehensively discussed in Appendix A 9 consists of monthly observations for a 21 years time frame ranging from January 1986 to January 2007. All the times series of use are selected from the FRED database in accordance with the underlying monetary structural models and are consistent with the series first utilized by Meese and Rogoff (1983a, [1]). As in our reference papers we decided to work using not seasonally adjusted times series in order to avoid the possible bias introduced by different seasonal adjustments on the structural parameters documented in Sims (1973a and 1973b, [10, 11]). Henceforth we decided to approach our model validation in two different ways fitting the models on seasonal adjusted and detrended times series and on untreated times series in levels. This will of course have important consequences for the interpretation of the model results. While detrended and seasonally adjusted stationary times series will allow an interpretability of the results the latter is not guaranteed for the not treated times series where spurious regressions might arise distorting the model interpretation. Given the fact, that the goal of this work is nonetheless a reliable forecast of FX-rates rather than the identification of the causal relation between macroeconomic variables and FX-rates an analysis of the series in levels is ultimately interesting for the analysis and will yield superior results in comparison to treated times series as in Meese and Rogoff (1983a, [1]). With respect to the times series adjustments we proceeded by detrending the series at first exploring three different possibilities. Firstly detrending via differentiation, secondly detrending through a linear time trend and thirdly detreding through a moving average filter. Detrending through differencing provided to be the most effective compared to linear detrending due to the quadratic behaviour displayed by the series. This approach was therefore applied to all of the series but the current account balance differentials, where the particular monotonic behaviour of the series required a moving average filter able to separate the rapidly fluctuating component of the series from the slow varying component. The obtained mean stationary series were consequently inspected for the presence of seasonality and appropriately differenciated to the point where no significance was found for seasonal units roots according to the methods proposed in Canova and Hansen (1995, [12]) and in Wang and Smith (2006, [13]).

3 Methodology

3.1 Modeling Approach

3.1.1 Structural Model

The basic structural model encompassing all of the different monetary models discussed in the introductory session is of the following form:

$$s = \beta_0 + \beta_1(m - m^*) + \beta_2(y - y^*) + \beta_3(r - r^*) + \beta_4(\pi - \pi^*) + \beta_5(TB - TB^*) + \varepsilon \tag{1}$$

where s represents the logarithm of the indirect quote of FX-rates, i.e. the foreign exchange value of a dollar unit, $m - m^*$ represents the logarithm of the U.S. and foreign country money mass supply differential, $y - y^*$ the logarithm of the U.S. and foreign GDP level, $r - r^*$ the short term U.S. forign country interest rate differential, $\pi - \pi^*$ the U.S. and foreign country inflation rate differential, $TB - TB^*$ the U.S. foreign country current account differential normalized to be one at the beginning of the sample period and finally where ε represents the error term of the regression capturing all of the other factors not expressed in the model.

The model above encompasses all of the monetary models discussed. In the specific the most basics monetary model, the Frenkel-Bilson model logically inferred from the PPP proposition assumes $\beta_4 = \beta_5 = 0$. The Dornbusch model allowing a sluggish price adjustment behaviour and predicting FX-overshooting assumes $\beta_5 = 0$ and finally the Hooper-Morton model poses no restriction on the coeffcients of equation 1. Such a structural model will consequently be estimated allowing for four different parametric models of interest, which will be discussed next.

3.1.2 Univariate Models

The most basic model that will be tested is an OLS model as in the benchmark papers of Meese and Rogoff (1983a, 1983b, [1, 2]). In this basic first model the coefficients of equation 1 will be computed without looking at any lagged effect. In contrast to it a second more flexible model will be applied to capture possible lagged effects of the macroeconomics fundamentals. In comparison to the Meese and Rogoff papers where the authors decided to capture the possibility of lagged terms by incorporating autoregressive models giving a higher importance on more recent observations we decided to apply the transfer function models widely spread in the fields of engineering such as control systems and electronic circuits. These models have been poorly discussed in the field of economics with the exception of Tustin (1957, [14]) that tried to make the point for applying the models into the economics modeling field.
Transfer function models relates a given set of inputs to an output variable through the following general formula

$$Y_t = \mu + \frac{(\omega_0 + \omega_1 B^1 + \cdots + \omega_s B^s)}{1 - \delta_1 B^1 - \cdots - \delta_r B^r} X_{t-b} + \varepsilon_t \tag{2}$$

where X represent a matrix of exogenous terms, μ the optional term modeling the mean of the series and ε the non-captured variation in the series. Moreover the above ratio represents the transform function of the regressors matrix and is especially caracterized by the order of the denominator and nominator terms. r, the order of the denominator term, expresses the rate of the decay pattern, where a higher term indicates a slower decay. s, the order of the denominator term, expresses the persistence of so called unpatterned spikes, that is the persistence of effects that are not captured in the decay pattern. Finally, the b teerm in the matrix of input represent the dead time, that is the time it takes for the dependent variable to react to some changes in the input matrix. This is of primary importance as it might very well be that some shift in macroeconomics fundamentals just start to display effects after a certain amount of time when the economics actors start to perceive the change.
Due to the flexible nature of the latter model, we believe that it is better suited and preferrable to capture the true distributed lags present in the structural model of equation 1 compare with the smoothed autoregressive model applied by Meese and Rogoff with the arbitrarly chosen smoothing term of 0.95 (See Meese and Rogoff (1983a pp. 7, [1])).

3.1.3 Multivariate Models

The above discussed models rely on the exogeneity of the independent variables. If the assumption fails the model will be biased and would lead to misleading conclusion as the independence of the sample distribution would not be guaranteed. In practice this poses an issue for the estimation of the structural model of equation 1. While some variables as the monetary mass and the output gap are commonly treated as exogenous variables in the underlying monetary models the practice suggest that such macroeconomic variables might very well be influenced by the movements of FX-rates. On the top of it other variables such as short term interest rates differentials are treated as endogenous even in the underlying monetary models and therefore require a different estimation compared to the one outlined in the models of the previous section.
To obviate the above issues Meese and Rogoff (1983a and 1983b, [1, 2]) analyzed the structural model of interest through a vector autoregressive model firstly introduced by Sims (1980, [15]). In the general case the model consists of a system of equations of the form

$$y_t = \Phi_0 + \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + \cdots + \Phi_n y_{t-n} + \varepsilon_t \tag{3}$$

where y is a vector containing the endogenous variables of interest, Φ_0 is a vector of constant, $\Phi_1, \ldots, \Phi_n$ are matrices describing the effect of lagged endogenous variables on the levels of the current variables and ε captures the equations specific error term. The resulting model will model the endogeneity present in the monetary structural model allowing a consistent OLS estimation as far as the error terms of the equations will be uncorrelated.
Despite the described vector autoregressive model well manages to model the endogeneity of macroeconomic variables we question whether a restricted form of it could yield more efficient and reliable estimates capturing the FX-rates and the monetary models relation. This is especially motivated by the cointegration theory developed by Engle and Granger (1987, [4]) and the well known evidence of non stationary macroeconomics times series [2]. This is especially important given the demonstrated evidence of Phillips (1986, [17]) that set down the theoretical fundamentals showing that parameter estimates of cointegrated series will not converge in probability and will not converge to any non-degenerate distribution in the asymptotic case if the case of a misspecified OLS estimate as potentially equation 3.
We propose therefore a test for cointegration among the macroeconomics series based on Johansen (1991, [18]) and we consequently propose a vector error correction model of the form

[2] See for instance Gil-Alana and Robinson (1997, [16])

$$
\begin{aligned}
\Delta y_t &= \Pi y_{t-1} + \sum_{i=1}^{p-1} \Phi^* \Delta y_{t-i} + \varepsilon_t \\
\Phi^* &= -\sum_{i=j+1}^{p} \Phi_i, \;\; j = 1, \dots, p-1 \\
\Pi &= -\left(I - \Phi_1 - \cdots - \Phi_p\right)
\end{aligned} \tag{4}
$$

where Πy_{t-1} of equation 4 represent the error correction term and y_i and Φ refer to the variables described in the unrestricted vector autoregressive model of 3.

3.2 Forecasting Approach

The four described models described above will be validated by looking at their ability to forecast FX-rates out of sample. In this sense the 245 observations sample is splitted in a training and validation sample. Three fourth of the total observations will be used for training the four models outlined above at first. In comparison to Meese and Rogoff (1983b, [2]) we will not try any restricted estimation based on the theoretical monetary models literature but will rather estimate unrestricted versions for all of the models outlined with the exception of the vector error correction model described in 4, given the by product VAR model restriction imposed by the latter.
All of the four different models will be estimated according to the most general structural model described in 1 without restrictions. Based on the estimation results augmented Mincer-Zarnowitz tests first presented in Mince and Zarnowitz (1969, [19]) will be estimated in order to check whether there is evidence in the sample to consider restricted monetary models.

Based on the first estimation we proceeded by calculating the out of sample performance of the different models applying a rolling forecast in analogy to the benchmark papers. This will consist of a reestimation of the four outlined models for each new forecasting point. Given the decision to estimate the out of sample model performance at one, three, six and twelve months lags the above corresponds of a model reestimation at such frequencies. Important is nonetheless to underline how the results of the Mincer-Zarnowitz tests will be extended for each of the subsequent models applied in the rolling forecast. This means that given statistical significant evidence for the Null of a restricted hypothesis in the first three fourth of the sample the same restricted model will be used for subsequent model estimations.
Finally, as in the benchmark papers, we will allow the univariate models described in 3.1.2 a richer set of information compared to the random walk. In the specific while the random walk and the multivariate model will use the $\mathscr{F}_{t-1} = F_0, \, \dots, \, F_{t-1}$ information set, where F_i represent a set containing all of the available information at timepoint i. By contrast the univariate models will dispose of $\mathscr{F}_t \setminus s_t$, where s_t represents the FX-rate at time point t. In simple terms this means that we are going to give the univariate models the vantage of using the actual realizations of macroeconomics variables at timepoint t for estimating the FX-rates at the corresponding time period without the need of estimating them.

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4 Note

While the forecasts generated in this study are based on models with freely-estimated coefficients, elsewhere [Meese and Rogoff (1983)] we try forecasting with the structural models using a grid of coefficient constraints drawn from the theoretical and empirical literature on money demand and purchasing power parity.

5 Why MAE?

A possible problem with all the techniques listed thus far is that they minimize criteria based on squared deviations. These type of criteria are inappropriate if, for example, exchange rates follow non-normal stable- Paretian distributions with infinite variance, as suggested by Westerfield (1977).

6 times series without adjustments

While the relative performance of the six univariate forecasting techniques is of interest in itself, we shall only report detailed results for the long AR model without trend, seasonal adjustment, or differencing. This model's performance characterizes those of the best univariate models; we will discuss the results of the other univariate models only to a lesser degree.

7 Headings: first level

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7.1 Headings: second level

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$$\xi_{ij}(t) = P(x_t = i, x_{t+1} = j | y, v, w; \theta) = \frac{\alpha_i(t) a_{ij}^{w_t} \beta_j(t+1) b_j^{v_{t+1}}(y_{t+1})}{\sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i(t) a_{ij}^{w_t} \beta_j(t+1) b_j^{v_{t+1}}(y_{t+1})} \tag{5}$$

7.1.1 Headings: third level

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8 Examples of citations, figures, tables, references

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Of note is the command `\citet`, which produces citations appropriate for use in inline text. For example,

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8.1 Figures

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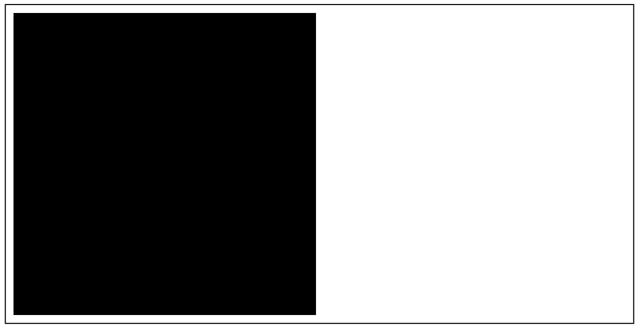

Figure 1: Sample figure caption.

Table 1: Sample table title

Part		
Name	Description	Size (μm)
Dendrite	Input terminal	$\sim$100
Axon	Output terminal	$\sim$10
Soma	Cell body	up to 10^6

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8.2 Tables

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8.3 Lists

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[3] Sample of the first footnote.

9 Appendix A

Mi piace la nutella.

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10 TO INCORPORATE??

forces are driving the currency, because the causes of the change will have different implications for the Canadian economy and may require a different monetary policy response.

References

[1] R. A. Meese and K. Rogoff, "Empirical exchange rate models of the seventies: Do they fit out of sample?," *Journal of international economics*, vol. 14, no. 1-2, pp. 3–24, 1983.

[2] R. Meese and K. Rogoff, "The out-of-sample failure of empirical exchange rate models: sampling error or misspecification?," in *Exchange rates and international macroeconomics*, pp. 67–112, University of Chicago Press, 1983.

[3] J. Bailliu, M. R. King, *et al.*, "What drives movements in exchange rates?," *Bank of Canada Review*, vol. 2005, no. Autumn, pp. 27–39, 2005.

[4] R. F. Engle and C. W. Granger, "Co-integration and error correction: representation, estimation, and testing," *Econometrica: journal of the Econometric Society*, pp. 251–276, 1987.

[5] J. A. Frenkel, "A monetary approach to the exchange rate: doctrinal aspects and empirical evidence," *The scandinavian Journal of economics*, pp. 200–224, 1976.

[6] M. Mussa, "The exchange rate, the balance of payments and monetary and fiscal policy under a regime of controlled floating," in *Flexible Exchange Rates and Stabilization Policy*, pp. 97–116, Springer, 1977.

[7] R. Dornbusch, "Expectations and exchange rate dynamics," *Journal of political Economy*, vol. 84, no. 6, pp. 1161–1176, 1976.

[8] P. Hooper and J. Morton, "Fluctuations in the dollar: A model of nominal and real exchange rate determination," *Journal of international money and finance*, vol. 1, pp. 39–56, 1982.

[9] D. C. Montgomery and G. Weatherby, "Modeling and forecasting time series using transfer function and intervention methods," *AIIE Transactions*, vol. 12, no. 4, pp. 289–307, 1980.

[10] C. A. Sims, "Seasonality in regression," *Journal of the American Statistical Association*, vol. 69, no. 347, pp. 618–626, 1974.

[11] C. A. Sims, "Distributed lags," 1973.

[12] F. Canova and B. E. Hansen, "Are seasonal patterns constant over time? a test for seasonal stability," *Journal of Business & Economic Statistics*, vol. 13, no. 3, pp. 237–252, 1995.

[13] X. Wang, K. Smith, and R. Hyndman, "Characteristic-based clustering for time series data," *Data mining and knowledge Discovery*, vol. 13, no. 3, pp. 335–364, 2006.

[14] A. Tustin, "The mechanism of economic systems," 1957.

[15] C. A. Sims, "Macroeconomics and reality," *Econometrica: journal of the Econometric Society*, pp. 1–48, 1980.

[16] L. A. Gil-Alana and P. M. Robinson, "Testing of unit root and other nonstationary hypotheses in macroeconomic time series," *Journal of Econometrics*, vol. 80, no. 2, pp. 241–268, 1997.

[17] P. C. Phillips, "Understanding spurious regressions in econometrics," *Journal of econometrics*, vol. 33, no. 3, pp. 311–340, 1986.

[18] S. Johansen, "Estimation and hypothesis testing of cointegration vectors in gaussian vector autoregressive models," *Econometrica: journal of the Econometric Society*, pp. 1551–1580, 1991.

[19] J. A. Mincer and V. Zarnowitz, "The evaluation of economic forecasts," in *Economic forecasts and expectations: Analysis of forecasting behavior and performance*, pp. 3–46, NBER, 1969.