Conventional and Unconventional Approaches to Exchange Rate Modeling and Assessment

Ron ALQUIST*
University of Michigan

Menzie D. CHINN**
University of Wisconsin and NBER

December 19, 2005

Acknowledgements: Paper presented at the ECB-Bank of Canada workshop on "Exchange rate determinants and economic impacts," Frankfurt, December 6-7, 2005. We thank the discussant, Paul De Grauwe, and the workshop participants for helpful comments. We also thank Gian Maria Milesi-Ferretti for providing data on foreign assets and liabilities. The views contained in this paper are solely those of the authors and do not necessarily represent those of the institutions the authors are associated with, or the ECB or Bank of Canada.

Correspondence:
* Department of Economics, University of Michigan, 611 Tappan St., Ann Arbor, MI 48109. Email: ralquist@umich.edu.
** Robert M. La Follette School of Public Affairs, and Department of Economics, University of Wisconsin, 1180 Observatory Drive, Madison, WI 53706. Tel/Fax: +1(608) 262-7397/2033. Email: mchinn@lafollette.wisc.edu

Abstract

We examine the relative predictive power of the sticky price monetary model, uncovered interest parity, and a transformation of the net exports variable. In addition to bringing a new model and data spanning a more recent period to bear, we implement the Clark and West (forthcoming) procedure for testing the significance of out-of-sample forecasts. We find that the interest rate parity relation holds better at long horizons and that a net exports variable does well in predicting exchange rates at short horizons in-sample. The successes, however, do not translate into comparable success out-of-sample.

Key words: exchange rates, monetary model, net foreign assets, interest rate parity, forecasting performance

JEL classification: F31, F47

1. Introduction

Over the course of the last year, movements in dollar exchange rates have proven as inexplicable as ever. In this study, we again take up the issue of whether there are enduring and significant instances where economic models can explain and predict future movements in exchange rates.

The paper makes three contributions. First, we examine the behavior of several key dollar exchange rates during the first euro/dollar cycle. There is ample interest in the behavior of the euro, aside from the synthetic euro, which provided the basis of previous studies, as in Chinn and Alquist (2000) and Schnatz et al. (2004). Second, we examine the relative performance of a model incorporating a role for net foreign assets, as suggested in the "financial adjustment" channel of Gourinchas and Rey (2005) as well as Lane and Milesi-Ferretti (2003). Third, we use a new test that is appropriate for testing nested models. Standard tests for the statistical significance of out-of-sample forecasts are wrongly sized.[1]

Gourinchas and Rey have recently forwarded the provocative view that dollar exchange rates can be well predicted by a procedure that takes into account a "financial adjustment" channel. The channel is the natural implication of intertemporal budget constraint that allows for valuation changes in foreign assets and liabilities. More broadly, there is a large literature that links foreign assets and liabilities to exchange rates

[1] The evaluation procedure also differs slightly from that in Cheung et al. (2005a,b). We evaluate the mean squared prediction error of the predicted change in the exchange rate rather than the level. In the context of the error correction forecasts we make, and conditioning on the current spot exchange rate, the resulting comparison is the same; to stay close to the spirit of the Clark and West (forthcoming) paper, however, we retain the comparison in changes.

(Lane and Milessi-Ferretti, 2005). The examination provides an opportunity to determine if the finding is replicable using alternative data sets, different sample periods, and different currencies.

In a recent paper, Engel and West (2005) have argued that one should not expect much exchange rate predictability, given that the fundamentals for exchange rates follow highly persistent processes and the discount factor for the fundamentals follows very closely a random walk. We do not dispute the view, especially given the negative results in Cheung et al.'s (2005a,b) comprehensive study of several competing models.[2] Yet, arguably, in that study, the most powerful tests were not deployed. In this study, we remedy the deficiency by using Clark and West (forthcoming) method.

We summarize the exchange rate models considered in the exercise in Section 2. Section 3 discusses the data and in-sample fit of the models. Section 4 outlines the forecasting exercise, estimation methods, and the criteria used to compare forecasting performance. The forecasting results are reported in Section 5. Section 6 concludes.

2. The Models and Some Evidence

We use the random walk model as our benchmark model, in line with previous work. As the workhorse model, we appeal to the Frankel (1979) formulation of the Dornbusch (1976) model, as it provides the fundamental intuition for how flexible exchange rates behave. The sticky price monetary model is:

$$s_t = \beta_0 + \beta_1 \hat{m}_t + \beta_2 \hat{y}_t + \beta_3 \hat{i}_t + \beta_4 \hat{\pi}_t + u_t, \quad (1)$$

[2] See Faust et al. (2003), while MacDonald and Marsh (1999), Groen (2000) and Mark and Sul (2001) provide more positive results.

where m is log money, y is log real GDP, i and π are the interest and inflation rate, and u_t is an error term. The circumflexes denote inter-country differentials. The characteristics of this model are well known, and we do not devote time to discussing the underlying theory. The money stock and the inflation rate coefficients should be positive; and the income and interest rate coefficients negative, as long as prices are sticky. If prices are perfectly flexible, either interest rates or inflation rates should enter in positively.

The specification is more general than it appears. The variables included in (1) encompass those employed in the flexible price version of the monetary model, as well as the micro-based general equilibrium models of Stockman (1980) and Lucas (1982). In addition, the sticky price model is an extension of equation (1), where the price variables are replaced by macro variables that capture money demand and overshooting effects. We do not impose coefficient restrictions in equation (1) because theory provides little guidance regarding the values of the parameters.

The next specification assessed is not a model *per se*; rather it is an arbitrage relationship – uncovered interest rate parity[3]:

$$s_{t+k} - s_t = \hat{i}_t^k \tag{2}$$

Where $\hat{i}_t^k$ is the interest rate of maturity k.[4] The relation need not be estimated to

[3] To be technically correct, (2) represents uncovered interest parity combined with unbiased expectations. This is sometimes termed the unbiasedness hypothesis.

[4] For notational consistency, we use the log approximation in discussing interest rate parity, but use the exact expression in the regressions and the forecasting exercises. The results do differ somewhat between the two methods, particularly when the sample includes the 1970s when interest rates were relatively high.

generate predictions.

The interest rate parity relationship is included in the forecast comparison exercise because it has recently gathered empirical support at long horizons (Chinn and Meredith, 2004), in contrast to the disappointing results at the shorter horizons. Cheung et al. (2005a,b) confirm that long-run interest rates appear to predict exchange rate levels better than alternative models.[5]

The third model is based upon Gourinchas-Rey (2005). Gourinchas and Rey (2005) log-linearize a transformation of the net exports variable around its steady state value. Appealing to the long run restrictions imposed by assumptions of stationarity of asset to wealth, liability to wealth, and asset to liability ratios, they find that either trade flows, portfolio returns, or both, adjust, in a statistical sense. By way of contrast, the intertemporal budget approach to the current account takes trade flows as the principal object of interest, probably because most of the simple models in this vein contain only one good.

The financial channel implies that net portfolio returns, *ret*, (which combine market and exchange rate change induced-valuation effects) exhibits the following relationship:

(3) $$ret_t = \gamma + \lambda nxa_{t-1} + Z_{t-1}\Xi + \varepsilon_t$$

where Z is a set of control variables, and

[5] Despite the finding, there is little evidence that long-term interest rate differentials – or equivalently long-dated forward rates – have been used for forecasting at the horizons we are investigating. One exception from the non-academic literature is Rosenberg (2001).

(4) $$nxa_t = \left|\frac{\mu_m}{\mu_x}\right| xm_t - \left|\frac{\mu_l}{\mu_x}\right| al_t + \frac{1}{|\mu_x|} xa_t$$

where these μ's are normalized weights; *xm* is the log export to import ratio; *al* is the log asset to liability ratio; and *xa* is the log export to asset ratio. When one normalizes the exports variable to have a coefficient of unity as in (4), Gourinchas and Rey describe the *nxa* variable as: "approximately the percentage increase in exports necessary to restore external balance (i.e., compensate for the deviation from trend of the net exports to net foreign asset ratio)." (2005, page 12).

They conclude that the financial adjustment channel is quantitatively important at the medium frequency – that is, asset returns do fair bit of the adjustment at horizons of up to two years; thereafter the conventional trade balance channels comes into greater force. Exchange rates, as part of the financial adjustment process as well as the trade balance process, occupy a dual role. They find that at the one quarter ahead horizon, 11% of the variance of exchange rate is predicted, while at one and three years ahead, 44% and 61% of the variance is explained. Specifically, they statistically outperform a random walk at all horizons between one to twelve quarters, using the Clark and West (forthcoming) test method.[6]

3. Data and In-sample Model Fit

To provide some insight into how plausible the models are, we conduct some regression

[6] They use a initial estimation window of 1952q1-1978q1, and roll the regressions for the cointegrating vector.

analysis to show whether the specifications make sense, based on in-sample diagnostics.[7]

3.1 Data

We rely upon quarterly data for the United States, Canada, U.K., and the Euro Area over the 1970q1 to 2004q4 period.[8] The exchange rate, money, price and income (real GDP) variables are drawn primarily from the IMF's *International Financial Statistics*. M1 is used for the money variable, with the exception of the UK, where M4 is used. For the money stocks, exchange rates, and interest rates, end-of-quarter rates are used.

The interest rate data used for the interest rate parity estimates are from the national central banks as well as Chinn and Meredith (2004).

The Euro Area data are drawn from the Area Wide Model, described in Fagan et al. (2001).

The end of year U.S. foreign asset and liability data are from Lane and Milesi-Ferretti (2005) and interpolated using quarterly financial account data.

The transformed net exports variable requires some discussion. The central point made by Gourinchas and Rey (2005) and Lane and Milesi-Ferretti (2005) is that cumulated trade balances can be very inaccurate measures of net foreign asset positions in an era of financial integration, i.e., where gross asset and liability positions are large relative to GDP, and are subject to substantial variation due to exchange rate induced valuation changes. Lane and Milesi-Ferretti provide end-of-year data on gross asset and

[7] For a discussion of why one might want to rely solely on in-sample diagnostics, see Inoue and Kilian (2004).
[8] Data series for the euro area begin around 1980.

gross liability positions, denominated in dollars. We generate quarterly data by distributing measured financial account balance data over the year.

See the Data Appendix for more detail.

3.2 Estimation and Results

Using DOLS, we check the monetary model for a long-run relationship between the exchange rate and the explanatory variables. This is implemented using dynamic OLS (Stock and Watson, 1993):

$$s_t = X_t\Gamma + \sum_{i=-2}^{+2} \Delta X_t B + u_t\,, \tag{5}$$

where *X* is the vector of explanatory variables associated with the monetary approach.

For the other models, the specifications take on an "error-correction"-like form. The interest rate parity relationship in (2) implies the annualized change in the exchange rate equals the interest rate differential of the appropriate maturity. The Gourinchas-Rey specification of equation (3) implies that exchange rate changes are related the lagged level of the *nxa*. In these instances, we rely upon standard OLS estimates, relying upon heteroskedasticity and serial correlation robust standard errors to conduct inference.[9]

Table 1 displays the estimated cointegrating vectors for the monetary model normalized on the exchange rate. Theory predicts that money enters with a positive

[9] For the *nxa* regressions, we follow the suggestion of Newey and West and set the truncation lag equal to $4(T/100)^{2/9}$. In the interest rate parity regressions, where under the unbiasedness null the errors follow an MA(k-1) process, we use a truncation lag of 2(k-1) indicated by Cochrane (1991).

coefficient, income with a negative coefficient, and inflation with a positive coefficient. Interest rates have a (negative) independent effect above and beyond that of inflation if prices are sticky, so that higher nominal interest rates, holding inflation constant, appreciate the home currency.

The estimated money coefficients are, as usual, wrong signed and/or insignificant. Money does have the right sign for Canada, but that is the sole case (and substantially smaller one, the value suggested by theory.). Income and interest rates typically have the right sign, but inflation appears to exert a more consistently significant effect. Hence, we have some slight evidence in favor of a long run cointegrating relationship between monetary fundamentals and nominal exchange rates in the three cases.

The interest rate parity results in Table 2 replicate those found in Chinn and Meredith (2004): at short horizons, the coefficient on interest rates point in a direction inconsistent with the joint null hypothesis of uncovered interest parity and unbiased expectations (note that the significance levels in this panel are for the null of the slope coefficient equaling unity).

For the euro/dollar rate, we report results for a sample that pertains to the post-EMU sample, and a longer one (back to 1990) relying upon the synthetic euro, and using the German 3 month rate as a proxy for the euro interest rate. In both cases, the forward discount points in the wrong direction, on average, with the bias more pronounced in the shorter post-EMU period.

At the long horizon of 5 years, interest rates point in the right direction, and the null of a unitary coefficient cannot be rejected at conventional levels. This pattern of results matches that reported in Cheung et al. (2005b), as well as Chinn and Meredith

(2004). While these are promising results, the adjusted R^2's are still quite low.

Finally, we turn to the regression involving transformed net exports. The series we have generated using the Lane and Milesi-Ferretti data is plotted in Figure 2. We cannot exactly replicate the patterns in the Gourinchas-Rey series, which is not surprising as we do not undertake as detailed a reconstruction of the underlying assets and liabilities.

Theory predicts the exchange rate depreciates in response to a negative value of the explanatory variable. Given the way in which the exchange rate is defined, this implies a negative sign. Table 3 reports some positive results, in that the coefficients are statistically significant in the right direction 8 out 9 times.

In addition, the effect appears more pronounced at the short and short to intermediate horizon (3 month, 1 year) than at 5 years. In addition, the adjusted R^2's for these regressions is fairly high by comparison to the long horizon interest rate regressions. These results augur well for positive results on the forecasting end.

4. Forecasting Procedure and Comparison

4.1 The Forecasting Exercise

In order to insure that our conclusions are not sensitive to the choice of a specific out-of-forecasting period, we use two out-of-sample simulation periods to assess model performance: 1987q2-2004q4 and 1999q1-2004q4. The former period conforms to the post-Louvre Accord period, while the latter spans the post-EMU period. The longer out-of-sample period (1987-2004) spans a period of *relative* dollar stability with one upswing and downswing in the dollar's value.

We adopt the convention in empirical exchange rate modeling of implementing "rolling regressions" established by Meese and Rogoff (1983). That is, estimates are applied over a given data sample, out-of-sample forecasts produced, then the sample is moved up, or "rolled," forward one observation before the procedure is repeated. The process continues until all the out-of-sample observations are exhausted. While the rolling regressions do not incorporate possible efficiency gains as the sample moves forward through time, the procedure potentially alleviates parameter instability, which is common in exchange rate modeling.

An error correction specification for the sticky price monetary model is used, while the competing models intrinsically possess an error correction nature. Returning to the monetary model, both the exchange rate and its economic determinants are I(1). The error correction specification allows for the long-run interaction effect of these variables, captured by the error correction term, in generating forecasts. If the variables are cointegrated, then the former specification is more efficient that the latter one and is expected to forecast better in long horizons. If the variables are not cointegrated, the error correction specification leads to spurious results. Since we detect evidence in favor of cointegration, we rely upon error correction specifications for the monetary models.

The general expression for the relationship between the exchange rate and fundamentals:

(6) $$s_t = X_t \Gamma + \varepsilon_t ,$$

where X_t is a vector of fundamental variables indicated in (1). The error correction estimation is a two-step procedure. In the first, the long-run cointegrating relation implied by (6) is identified using DOLS. The estimated cointegrating vector ($\tilde{\Gamma}$) is incorporated into the error correction term, and the resulting equation

$$(7) \qquad s_t - s_{t-k} = \delta_0 + \delta_1 (s_{t-k} - X_{t-k}\tilde{\Gamma}) + u_t$$

is estimated via OLS. Equation (7) is an error correction model stripped of short run dynamics. Mark (1995) and Chinn and Meese (1995) use a similar approach, except that they impose the cointegrating vector *a priori*. The specification is motivated by the difficulty in estimating the short run dynamics in exchange rate equations.[10] Our estimates of the *long-run* cointegrating relationship vary as the data window moves.[11]

4.2 Forecast Comparison

To evaluate the forecasting accuracy of the different structural models, we use the adjusted-mean squared prediction error (MSPE) statistic proposed by Clark and West (forthcoming). Under the null hypothesis, the MSPE of a zero mean process is the same as the MSPE of the linear alternative. Despite the equality, one expects the alternative model's sample MSPE to be larger than the null's. To adjust the upward bias, Clark and

---

[10] We opted to exclude short-run dynamics in equation (7) for two reasons. First is that the use of equation (7) yields true *ex ante* forecasts and makes our exercise directly comparable with, for example, Mark (1995), Chinn and Meese (1995) and Groen (2000). Second, the inclusion of short-run dynamics creates additional demands on the generation of the right-hand-side variables and the stability of the short-run dynamics that complicate the forecast comparison exercise beyond a manageable level.

[11] Restrictions on the β-parameters in (1) are not imposed because in many cases we do not have strong priors on the exact values of the coefficients.

West propose a procedure that performs well in simulations (Clark and West, forthcoming).

The test statistic is the difference between the MSPE of the random walk model and the MSPE from the linear alternative, which is adjusted downwards to account for spurious in-sample fit. A value larger (smaller) than zero indicates the linear model (random walk) outperforms the random walk (linear model)

Our inferences are based on a formal test for the null hypothesis of no difference in the accuracy (i.e. in the MSPE) of the two competing forecasts, the linear (structural) model and the driftless random walk. The difference between the two MSPEs is asymptotically normally distributed.[12] For forecast horizons beyond one period, one needs to account for the autocorrelation induced by the rolling regression. We use Clark and West's proposed estimator for the asymptotic variance of the adjusted mean between the two MSPEs, which is robust to the serial correlation (Clark and West, forthcoming).

5. Comparing the Forecasts

Table 4 presents the results of comparing the forecasts. The top entry in each cell is the difference in the MSPEs (positive entries denote out-performance of a random walk). The Clark-West statistic is displayed below (Diebold-Mariano statistic for the interest rate parity results); this can be read as a *z*-statistic.

At most horizons, the interest rate parity model does about as well as the random walk. In no case is the MSPE of the interest rate parity model statistically different from the random walk model, although the point estimate of the interest parity model's MSPE

[12] Since the interest rate parity coefficient of unity is imposed, rather than estimated, we used the Diebold-Mariano (1995) test statistic.

tends to be smaller than the estimate of the random walk's MSPE at long horizons than at short. This is surprising, given results in the previous literature, including Cheung et al. (2005a,b). The reason for the difference may be that: (1) the sample encompasses four years of convergence of interest rates; and (2) we omit the yen, a currency for which interest rate parity substantially outperformed a random walk in Cheung et al. Future work will work to isolate the specific cause for the differences in the results.

The sticky price monetary model does not do altogether that poorly. In eight out of twelve cases, it outperforms the random walk, although only in two instances (USD/GBP 4 quarters ahead post 1987 and USD/EUR 1 quarter ahead post 1999) is the outperformance statistically significant. This finding is remarkable considering the fact that the cointegrating vector is estimating using a rolling window[13], rather than the entire sample, and the considerable (empirical) disrepute the monetary model is held in.

We find some favorable support for the transformed net exports model. It outperforms the random walk at short horizons for the pound and the euro (post-1987 and post-1999 respectively). The 1-quarter ahead forecast is statistically significant at the 10% level. The results are less favorable at long horizons and, interestingly, are not particularly positive for the Canadian dollar. Both of these results are consistent with those obtained by in Gourinchas and Rey (2005).

Figure 3 shows the best and worst forecast for each country, according to the MSPE. Among the best forecasts, none of the models comes anywhere near matching the dynamics of the change in the log spot rate. In particular, the *nxa* model, which does

[13] As noted in Cheung et al. (2005a,b), the papers in which a random walk are outperformed out-of-sample by the sticky price monetary model in a cointegration framework usually involve a cointegrating vector estimated over the entire sample, as in MacDonald and Taylor (1994).

strikingly well at tracking the exchange rate in Gourinchas and Rey at short horizons, does not stand out in our forecasts. It does not do badly, but it does not have the same out-of-sample forecasting ability either.

It is worthwhile to speculate why we might not be able to replicate the results Gourinchas and Rey obtain. First, our measure of gross assets and liabilities differs from those of Gourinchas and Rey; we rely upon the Lane and Milesi-Ferretti figures, while Gourinchas and Rey undertook a detailed reconstruction of U.S. asset and liability stocks. Second, as we have only annual data, we must estimate the intra-year stocks of assets and liabilities. Third, we do not have as long a sample to estimate the relationships. Fourth, we conduct our out-of-forecasting exercises over different samples. There is no particular reason that we should exactly replicate their results.

In addition, the main implication of the Gourinchas-Rey approach pertains to multilateral exchange rate returns, rather than to bilateral exchange rates that we examine. To the extent that there are not big valuation effects on assets and liabilities for certain currencies (say, the Canadian dollar), one should not necessarily expect the transformed net exports variable to have much predictive power for the USD/CAD exchange rate.

Interestingly, in no case is the performance of any of the models significantly worse than the random walk, in a statistical sense. This result *does* stand in contrast to the results reported in Cheung et al. (2005a,b), indicating that some of the poor performance of the structural models is attributable to the effect outlined by Clark and West (forthcoming) – namely the extra noise introduced by the estimation procedure.

6. Concluding Remarks

In this study, we have re-examined the evidence in support of a new model of exchange rate modeling, motivated by intertemporal budget constraints, and contrasted it with the results based upon interest rate parity and a conventional sticky price monetary model. In addition, we have relied upon a procedure for testing for statistical significance that has better size characteristics than the standard approach. And finally, we have leveled these approaches against a new currency, the euro. In this regard, we rely upon both actual data post-EMU, and synthetic data that begin earlier.

In sum, we conclude:

- We cannot identify a model that reliably outperforms a random walk model, despite the use of an improved test.
- On the other hand, this better sized test forwarded by Clark and West indicates that the out-of-sample performance of structural models is not as poor as has been suggested by earlier statistical tests.
- The euro/dollar exchange rate – both its synthetic actual version – shares many of the same attributes that the deutschemark/dollar rate exhibited in terms of predictability and relevant determinants.
- The model that relies upon a log-linearized version of net exports variable does not do altogether too badly relative to the other models. However, perhaps for reasons related to data and sample differences, we are unable to exactly replicate the out-performance documented by Gourinchas-Rey.

These findings suggest certain immediate extensions and corrections. First, we hope to extend our estimates to multilateral effective exchange rates, although such an exercise will not be straightforward because the nature of the effective exchange rates will differ between models. Second, we intend to check the net export model using alternative US government data. Third, we plan to extend the analysis to the Japanese yen/dollar rate. Fourth, instead of relying upon interest rate parity, we can appeal to the entire term structure of interest differentials, as suggested by Clarida et al. (2001).

A more substantive change to the paper is suggested by a consideration of the boundaries of the study. We have only evaluated linear models, eschewing functional nonlinearities or deterministic nonlinearities. Yet, we know that there is an important body of literature that points to theoretical (De Grauwe and Grimaldi, 2005; De Grauwe et al., 2005) and empirical work suggesting the importance of certain types of nonlinearities (Engel and Hamilton, 1990; Taylor, Peel and Sarno, 2001; Kilian and Taylor, 2003).

In future work, we hope to augment the models we have examined with a specification that mimics the smooth transition threshold autoregression models of PPP. Moving into nonlinear models complicates the process of estimation (especially in the recursive setting we have adopted), and inference – the tests for comparative performance based on MSPE have to be modified – but this may be an avenue of exploration that will prove profitable.

References

Cheung, Yin-Wong, Menzie Chinn and Antonio Garcia Pascual, 2005, "Empirical Exchange Rate Models of the Nineties: Are Any Fit to Survive?" *Journal of International Money and Finance* 24 (November): 1150-1175 (a).

Cheung, Yin-Wong, Menzie Chinn and Antonio Garcia Pascual, "Recent Exchange Rate Models: In-Sample Fit and Out-of-Sample Performance," in Paul DeGrauwe (editor), *Exchange Rate Modelling: Where Do We Stand?* (Cambridge: MIT Press for CESIfo, 2005): 239-276 (b).

Chinn, Menzie and Ron Alquist, 2000, "Tracking the Euro's Progress," *International Finance 3*(3) (November): 357-374.

Chinn, Menzie and Richard Meese, 1995, "Banking on Currency Forecasts: How Predictable Is Change in Money?" *Journal of International Economics* 38: 161-178.

Chinn, Menzie and Guy Meredith, 2004, "Monetary Policy and Long Horizon Uncovered Interest Parity," *IMF Staff Papers* 51(3): 409-430.

Clarida, Richard, Lucio Sarno, Mark Taylor, Giorgio Valente, 2001, "The Out-of-Sample Success of Term Structure Models as Exchange Rate Predictors: A Step Beyond," *NBER Working Paper* No. 8601 (November).

Clark, Todd E. and Michael McCracken, 2004, Evaluating Long–Horizon Forecasts," mimeo (Columbia, MO: University of Missouri, February).

Clark, Todd E. and Kenneth D. West, forthcoming, "Using Out-of-Sample Mean Squared Prediction Errors to Test the Martingale Difference Hypothesis," *Journal of Econometrics.*

Cochrane, John, 1991, "Production-Based Asset Pricing and the Link between Stock Returns and Economic Fluctuations," *Journal of Finance 46* (March): 207-234.

De Grauwe, Paul, Roberto Dieci and Marianna Grimaldi, 2005, "Fundamental and Non-Fundamental Equilibria in the Foreign Exchange Market. A Behavioural Finance Framework," *CESIfo Working Paper* No.1431, March.

De Grauwe, Paul and Marianna Grimaldi, 2005, "The Exchange Rate and its Fundamentals in a Complex World," *Review of International Economics* 13(3): 549-575.

Dornbusch, Rudiger. 1976. "Expectations and Exchange Rate Dynamics," *Journal of Political Economy* 84: 1161-76.

Diebold, Francis X. and Roberto Mariano, 1995, “Comparing Predictive Accuracy,” *Journal of Business and Economic Statistics* 13: 253-265.

Engel, Charles and James Hamilton, 1990, “Long Swings in the Exchange Rate: Are They in the Data and Do Markets Know It?” *American Economic Review* 80: 689-713.

Engel, Charles and Kenneth D. West, 2005, “Exchange Rates and Fundamentals,” *Journal of Political Economy* 113(2): 485-517.

Fagan, Gabriel, Jérôme Henry, and Ricardo Mestre, 2001, “An Area-wide Model (AWM) for the euro area,” *ECB Working Paper* No. 42: (Frankfurt: ECB, January).

Faust, Jon, John Rogers and Jonathan Wright, 2003, “Exchange Rate Forecasting: The Errors We’ve Really Made,” *Journal of International Economics* 60: 35-60.

Frankel, Jeffrey A., 1979, “On the Mark: A Theory of Floating Exchange Rates Based on Real Interest Differentials,” *American Economic Review* 69: 610-622.

Gourinchas, Pierre-Olivier and Helene Rey, 2005, “International Financial Adjustment,” *NBER Working Paper* No. 11155 (February).

Groen, Jan J.J., 2000, “The Monetary Exchange Rate Model as a Long–Run Phenomenon,” *Journal of International Economics* 52: 299-320.

Inoue, Atsushi and Lutz Kilian, 2004, "In-Sample or Out-of-Sample Tests of Predictability: Which One Should We Use?" *Econometric Review* 23(4): 371 - 402

Kilian, Lutz and Mark Taylor, 2003, “Why Is It So Difficult to Beat the Random Walk Forecast of Exchange Rates,” *Journal of International Economics* 60: 85-108.

Lane, Philip R. and Gian Maria Milesi-Ferretti, 2005, “The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities,” mimeo, Trinity College Dublin and IMF.

Lucas, Robert, 1982, “Interest Rates and Currency Prices in a Two-Country World,” *Journal of Monetary Economics* 10: 335-359.

McCracken, Michael and Stephen Sapp, 2004, “Evaluating the Predictability of Exchange Rates using Long Horizon Regressions: Mind Your p’s and q’s!,” mimeo (Columbia, MO: University of Missouri, June).

MacDonald, Ronald and Ian Marsh, 1999, *Exchange Rate Modeling* (Boston: Kluwer).

MacDonald, Ronald and Mark P. Taylor, 1994, “The monetary model of the exchange rate: long-run relationships, short-run dynamics and how to beat a random walk," *Journal of International Money and Finance* 13: 276-290.

Mark, Nelson, 1995, "Exchange Rates and Fundamentals: Evidence on Long Horizon Predictability," *American Economic Review* 85: 201-218.

Mark, Nelson and Donggyu Sul, 2001, "Nominal Exchange Rates and Monetary Fundamentals: Evidence from a Small post-Bretton Woods Panel," *Journal of International Economics* 53: 29-52.

Meese, Richard, and Kenneth Rogoff, 1983, "Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?" *Journal of International Economics* 14: 3-24.

Meese, Richard, and Kenneth Rogoff, 1988, "Was It Real? The Exchange Rate-Interest Differential Relation over the Modern Floating-Rate Period," *Journal of Finance* 43: 933-47.

Meese, Richard, and Andrew K. Rose, 1991, "An Empirical Assessment of Non-Linearities in Models of Exchange Rate Determination," *Review of Economic Studies* 58: 603-619.

Obstfeld, Maurice and Kenneth Rogoff, 1995, "Exchange Rate Dynamics Redux," *Journal of Political Economy* 91: 675-687.

Rosenberg, Michael, 2001, "Investment Strategies based on Long-Dated Forward Rate/PPP Divergence," *FX Weekly* (New York: Deutsche Bank Global Markets Research, 27 April), pp. 4-8.

Schnatz, Bernd, Focco Vijselaar, and Chiara Osbat, 2004, "Productivity and the Euro-Dollar Exchange Rate," *Review of World Economics* 140(1).

Stock, James H. and Mark W. Watson, 1993, "A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems," *Econometrica 61*(4): 783-820.

Stockman, Alan, 1980, "A Theory of Exchange Rate Determination," *Journal of Political Economy* 88: 673-698.

Taylor, Mark P. Taylor, David A. Peel and Lucio Sarno, 2001, "Nonlinear Mean-Reversion in Real Exchange Rates: Toward a Solution to the Purchasing Power Parity Puzzles," *International Economic Review* 42(4): 1015- .

Appendix 1: Data

Unless otherwise stated, we use seasonally-adjusted quarterly data from the *IMF International Financial Statistics* ranging from the second quarter of 1973 to the last quarter of 2004. The exchange rate data are end of period exchange rates. The output data are measured in constant 2000 prices. The consumer price indexes also use 2000 as base year. Inflation rates are calculated as 4-quarter log differences of the CPI.

Canadian M1 and UK M4 are drawn from *IFS*. The US M1 is drawn from the Federal Reserve Bank of St. Louis's FRED II system. The euro area M1 is drawn from the ECB's Area Wide Macroeconomic Model (AWM) described in Fagan et al. (2001), located on the Euro Area Business Cycle Network website (http://www.eabcn.org/data/awm/index.htm).

The overnight interest rates are from the respective central banks. The three-month, annual and five-year interest rates are end-of-period constant maturity interest rates from the national central banks. For Canada and the United Kingdom, we extend the interest rate time series using data from IMF country desks. See Chinn and Meredith (2004) for details. We use German interest rate data from the Bundesbank to extend the Euro Area interest rates earlier.

The annual foreign asset and liability data are from Lane and Milessi-Ferretti (2005). The quarterly data are interpolated by cumulating financial account flows from *IFS* and forcing the cumulative sum to equal the year end value from Lane and Milessi-Ferretti (2005). Thus, the quarterly positions grow at the rate given by the financial account data in *IFS*, subject to the constraint that the year end value equals Lane and Milessi-Ferreti's.

To construct the transformed net exports variable, we backed out the weights implied by the point estimates on page 13 of Gourinchas and Rey using the estimates from the DOLS regressions on page 12. The problem reduced to solving 3 equations in 3 unknowns, where the unknowns were the weights normalized on μ_x. The weights are $\mu_x /(\mu_x +1) = 1.0964$; $\mu_l /(\mu_x +1)=.7231$; and $1/(\mu_x+1) = -0.0929$.

Table 1: DOLS Estimates of the Monetary Model

	EUR	GBP	CAD
Money	-0.108	-0.192	0.112^{**}
	(0.297)	(0.198)	(0.053)
Output	-0.996	-2.384	1.723^{***}
	(0.957)	(1.597)	(0.472)
Interest rates	-1.974	-0.634	-0.684
	(1.325)	(1.536)	(0.805)
Inflation	8.102^{**}	1.196	2.547^{***}
	(4.055)	(1.424)	(1.193)
Adj. R-sq.	0.59	0.20	0.61
Sample	81Q4-04Q4	75Q4-04Q4	75Q2-04Q4
T	93	117	119

Notes: Point estimates from DOLS(2,2). Newey-West HAC standard errors in parentheses. *(**)(***) indicates statistical significance at the 10% (5%) (1%) level.

Table 2: Interest Rate Parity Regressions

	EUR	EUR	GBP	CAD
3-month	-7.66^{***}	-1.00	-1.58^{***}	-0.84^{***}
	(3.13)	(1.65)	(0.99)	(0.47)
Adj. R-sq.	0.13	-0.01	0.02	0.01
Sample	99Q2-04Q4	90Q4-04Q4	75Q2-04Q4	75Q1-04Q4
T	23	104	119	120
1-year	...	...	-0.32	-0.57
			(0.82)	(0.55)
Adj. R-sq.	...	...	-0.01	0.01
Sample	...	...	76Q2-04Q4	75Q1-04Q4
T	...	...	115	120
5-year	...	1.57	0.51	1.03
		(0.38)	(0.37)	(0.31)
Adj. R-sq.	...	0.36	0.03	0.05
Sample	...	90Q1-04Q4	80Q1-04Q4	80Q1-04Q4
T	...	60	100	100

Notes: Point estimates from OLS. Newey-West HAC standard errors in parentheses. *(**)(***) indicates statistical significance at the 10% (5%) (1%) level.

Table 3: Transformed Net Exports

	EUR	GBP	CAD
3-month	-0.59^{***}	-0.43^{***}	-0.17^{***}
	(0.21)	(0.18)	(0.10)
Adj. R-sq.	0.07	0.04	0.02
Sample	79Q1-04Q4	75Q2-04Q4	75Q2-04Q4
T	104	119	108
1-year	-0.50^{***}	-0.40^{***}	-0.19^{***}
	(0.162)	(0.12)	(0.08)
Adj. R-sq.	0.19	0.14	0.13
Sample	79Q4-04Q4	75Q2-04Q4	75Q2-04Q4
T	101	119	108
5-year	-0.27^{***}	-0.11^{***}	-0.13^{***}
	(0.05)	(0.05)	(0.03)
Adj. R-sq.	0.30	0.07	0.36
Sample	83Q4-04Q4	79Q1-04Q4	79Q1-04Q4
T	85	104	104

Notes: Point estimates from DOLS(2,2). Newey-West HAC standard errors in parentheses. *(**)(***) indicates statistical significance at the 10% (5%) (1%) level.

Table 4: MSPE difference and Z-score for Clark-West Test

		(1)	(2)	(3)	(4)	(5)	(6)
			1987Q2-2004Q4			1999Q1-2004Q4	
	Horizon	IRP	S-P	NXA	IRP	S-P	NXA
Panel A: CAD/USD							
	1	-0.01	0.00	-0.00	-0.01	0.01	0.00
		-0.34	0.53	-1.10	-0.20	1.00	0.56
	4	-0.09	-0.00	-0.03	-0.12	0.01	0.06
		-1.57	-0.12	-0.55	-1.28	0.49	0.46
	20	0.12	-0.48	0.33	-0.04	...	...
		0.26	-0.14	0.27	-0.06	...	...
Panel B: GBP/USD							
	1	-0.01	0.00	-0.00	-0.02	-0.00	0.03
		-0.11	0.67	-0.15	-0.39	-0.95	2.01
	4	-0.18	0.05	-0.23	-0.18	0.01	0.24
		-1.12	1.63	-0.63	-1.19	0.29	1.11
	20	-0.50	-1.21	0.03	0.05	...	...
		-2.59	-0.33	0.01	0.07	...	...
Panel C: EUR/USD							
	1	-0.01	...	0.08	-0.02	0.06	0.04
		-0.10	...	1.75	-0.60	2.10	1.38
	4	...	...	-0.46	...	0.20	0.62
		...	...	-0.88	...	1.34	0.83
	20	2.91	...	...	0.70	...	...
		1.01	...	...	1.89	...	...

Notes: IRP: Interest parity model; S-P: Sticky price monetary model; NXA: Transformed net exports model. The cell's first entry is the Clark-West test statistic times 100. The entry underneath is the z-score for the null hypothesis of no difference between the random walk and the linear alternative. For the interest rate parity forecasts, the z-score is the Diebold-Mariano (1995) test statistic. In some cases, 20-quarter ahead forecasts omitted because the Clark-West procedure requires the forecast sample be greater than two times the forecast horizon.

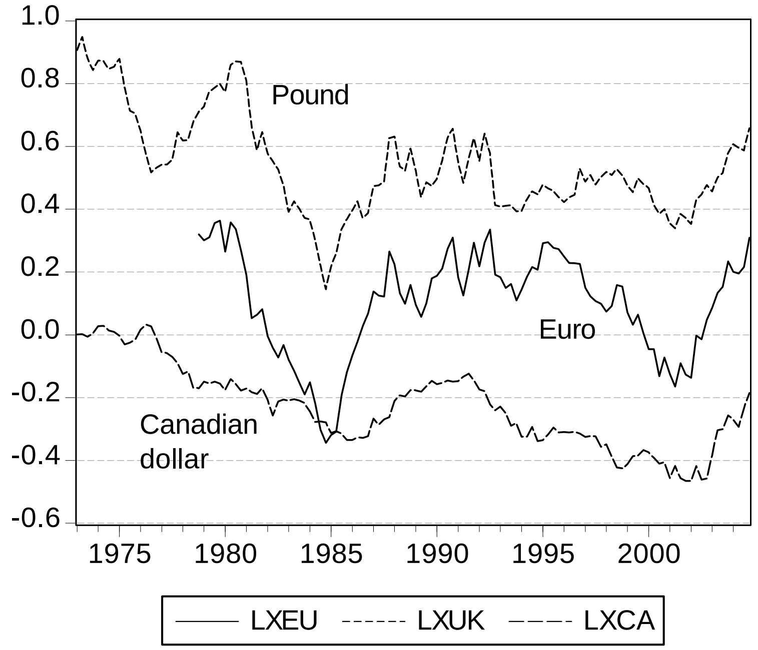


Figure 1: Synthetic and actual euro, UK pound and Canadian dollar exchange rates, end of quarter, in logs.

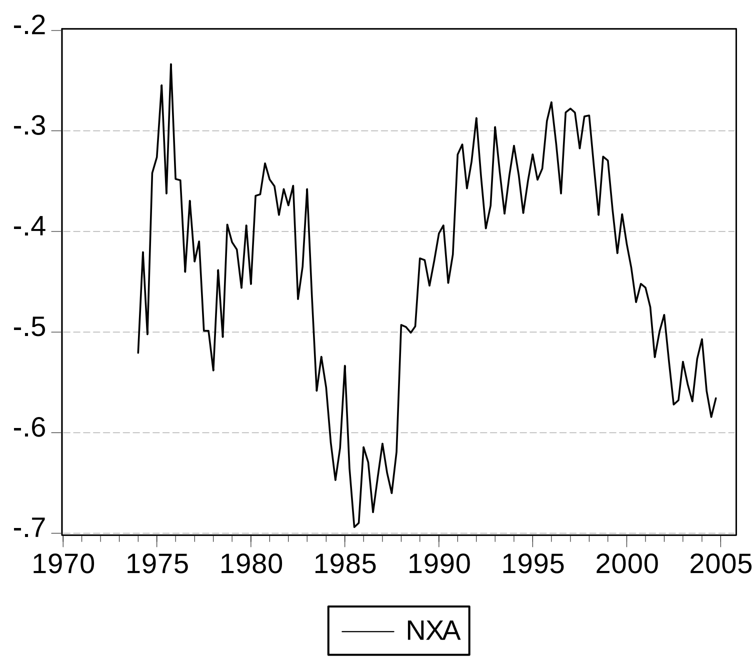
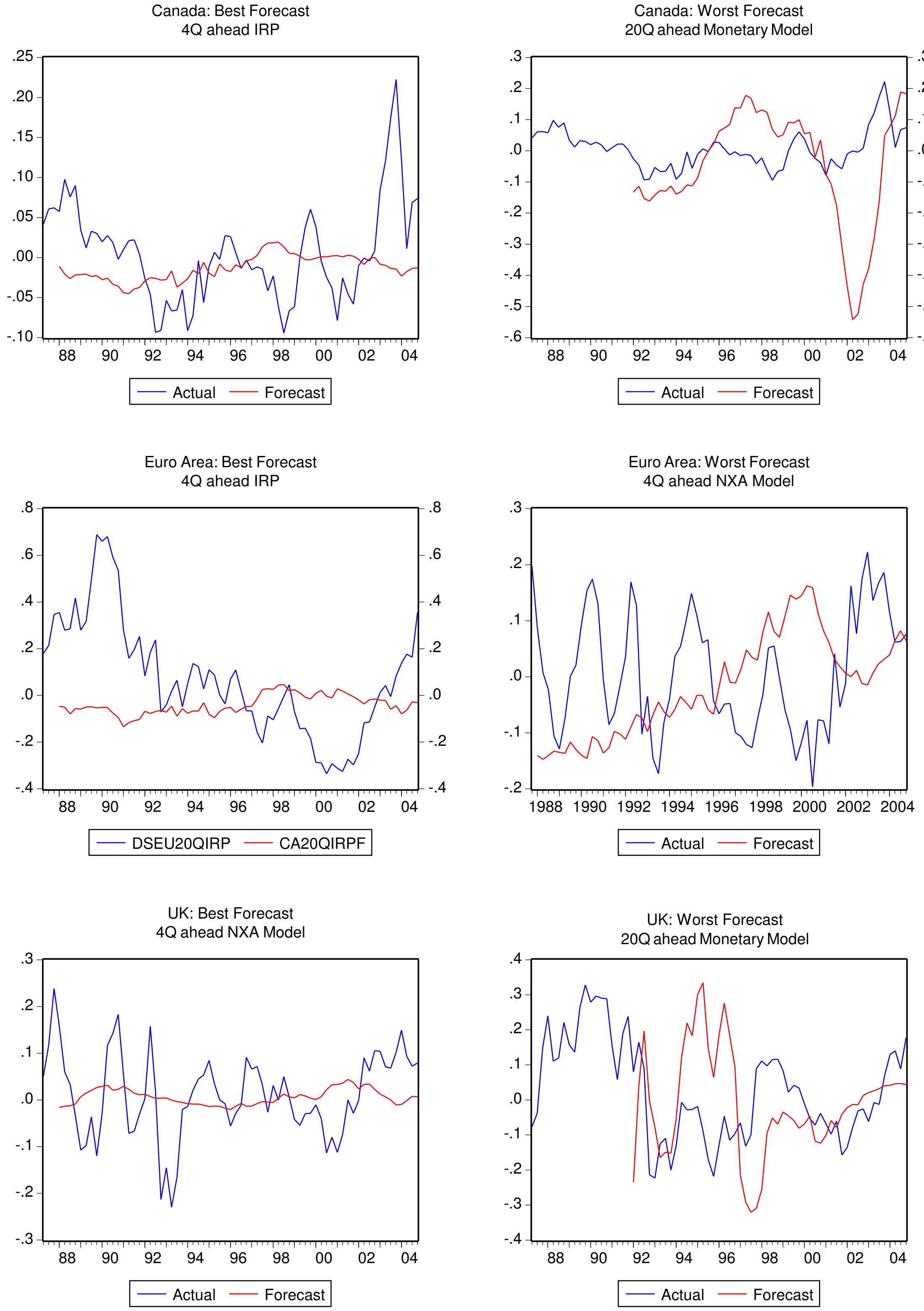


Figure 2: Transformed U.S. net exports to net foreign assets variable.

Figure 3: Best and Worst Forecasts



Notes: Best and worst determined by mean-square prediction error.