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The Taylor Rule, Wealth Effects and the Exchange Rate

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Abstract

The aim of this study is to develop models of the Taylor rule and a Taylor rule based exchange rate model incorporating wealth effects, as represented by both asset prices and asset wealth. In addition these wealth effects are further divided into stock market and housing wealth. Using data for Australia, Sweden, UK and the US, the Taylor model is estimated and then used to forecast out-of-sample. The results suggest that the effects of the asset prices and wealth on the Taylor rule are mixed and depend on the country and the form the wealth takes. The out-of-sample forecast performance of both the wealth augmented Taylor rule model and Taylor rule exchange rate model are then compared with the conventional Taylor Rule model and a random walk and overall the wealth augmented models outperform the conventional model and random walk in these countries.

Keywords: exchange rate, wealth effect, forecast

JEL classification: F30, F37

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The aim of this study is to develop models of the Taylor rule and a Taylor rule based exchange rate model incorporating wealth effects, as represented by both asset prices and asset wealth. Using data for Australia, Sweden, UK and the US, the results suggest that the effects of the asset prices and wealth on the Taylor rule are mixed and depend on the country and the form the wealth takes. The out-of-sample forecast performance of both the wealth augmented Taylor rule model and Taylor rule exchange rate model outperform the conventional models and random walk in these countries.

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1 Introduction

The relationship between monetary policy and asset market movements is a topic of perennial interest to policy makers. Following the late 1980s Japanese asset price bubble and the 2008 international financial crisis, both of which were a result of rapid asset price rises associated with excessive monetary easing, central banks have become more aware of the importance of the financial markets and wealth composition in monetary policy instruments. During the 1990s, the world experienced a sharp rise in households' net wealth and the financial markets became more integrated, including the foreign exchange, equity and housing markets. All these changes have exposed the need for a better understanding of the linkages between policy instruments and wealth composition.

The importance of asset prices in conducting monetary policy has been analysed for a variety of reasons. For example, there could be a direct impact of asset prices on economic activity as a result of: (i) wealth effects on consumption; (ii) changes in investment through Tobin's Q; (iii) wealth effects on monetary and fiscal policy. In addition excessive fluctuations in asset prices may impose a serious risk to financial stability. Moreover, as reported by Gilchrist and Leahy (2002), asset prices tend to incorporate information from a wide range of sources in a timely manner, and might therefore act as useful proxies for the underlying state of the economy, as well as future economic activity.

Since inflation targeting was introduced in the 1990s, the Taylor rule has become the dominant approach to determining interest rates and monetary policy in general. Given the importance of the Taylor rule and exchange rate to the economy as a whole, especially in the conduct of monetary policy, it is important to understand what factors determine interest rate movements and how they interact with other assets markets.

This study combines two areas of the existing literature, where various wealth effects have been included into the Taylor rule and also where wealth effects have been added to conventional exchange rate models, in order to improve the model and its forecasting performance. Specifically, we develop a model of the Taylor rule interest rate reaction functions which incorporate a measure of both housing and equity wealth. These specifications are then used as the basis for out-of-sample forecasting using the Taylor rule based exchange rate of Molodstova et al (2008) and Molodstova and Papell (2009). We have followed the approach of Molodstova et al (2008) in that after estimating the wealth augmented Taylor rule model, we have then concentrated on out-of-sample forecasting of both the interest rate and exchange rate.

The measures of wealth used in this study include both asset prices and measures of household wealth, as Case et al. (2005) suggests, both have varying degrees of influence on the macro-economy. Following the approach of Castro and Sousa (2012), the relationship between monetary policy and asset markets are classified as a "price effect", whilst the importance of wealth composition in conducting monetary policy are identified as a "quantity effect".

We contribute to the existing literature by including various wealth effects within the Taylor rule approach and the use of out-of-sample forecasting to determine if the inclusion of asset prices improves the out-of-sample forecasts. This facilitates insights into the response of both monetary policy and the monetary policy derived exchange rate to developments in housing and equity markets. A further contribution is our analysis into the reaction of monetary policy to wealth composition and asset prices and whether monetary policy responds to them in the same way. Also as yet there has been no attempt to use the Taylor rule framework to investigate the relationship between asset prices and exchange rate models and this is the first study to use this approach to determine if there is a subsequent improvement in the predictability of exchange rates as a result of adding the wealth effect. Additionally, we investigate the difference between quasi-real time quadratic and HP detrended output gaps. This is done by comparing both the performance of the Taylor rule models and the performance of the exchange rate models under both measures. We have also used a wide variety of forecast performance tests as well as the Rossi fluctuation test, which assesses the stability of the forecasts.

The main results from this study are that there is evidence of wealth effects being important determinants of interest rates, with the asset wealth being more significant than asset prices. Also the addition of wealth effects to the models has improved the forecasts of both the Taylor rule model and the corresponding exchange rate models. This result has important policy implications for central banks in terms of the need to include information on asset markets when determining monetary policy and when predicting future movements in the main policy instruments.

Following the introduction, there is a literature review on the use of wealth effects in macroeconomic models, then in section 3 there is a description of the various models used. In section 4 we provide a discussion of the data and empirical approach and the Taylor rule empirical results are then analysed in section 5. In section 6 we assess the results of out-of-sample forecasting using the Taylor rule based exchange rate model. Finally we offer some concluding comments.

2. Literature Review

Although there is only limited literature linking asset markets to the Taylor rule based exchange rate models, there is a body of literature linking assets markets to the Taylor rule (Semmler and Zhang, 2007) and monetary policy (Friedman, 1988), as noted in Castro and Sousa (2012). Following the financial crisis in 2008, it has become evident that asset prices in general and house prices in particular are extremely important in the conduct of monetary policy. Before considering the open economy aspects, we will first analyse the importance of the asset markets to monetary policy and the macroeconomy in general.

Much of the early work on the effects of asset prices on the macroeconomy has concentrated on the importance of wealth in the consumption function. A number of studies have assessed the importance of wealth effects through asset prices on levels of consumption, including Case *et al* (2005) who find wealth effects, especially house prices are an important determinant of consumption. Peltonen et al., (2012) find similar results, using a panel data approach, showing that wealth effects are significant in 14 emerging economies, although the importance of housing and financial wealth differs across these countries. Jawadi et al., (2014) find evidence of asymmetry and time varying relationships between wealth and consumption in the UK and USA, although less evidence in the Euro area and Jawadi and Sousa (2014) also find evidence of an important wealth effect on consumption with the link varying across the range of consumption growth. Other studies which have also found evidence of this relationship include Sousa, (2010a) and Afonso and Sousa (2011a).

In addition a number of studies have identified the importance of the wealth effect for fiscal policy including Afonso and Sousa (2011b, 2012) who show that there are significant interactions between fiscal policy, stock prices and house prices. Agnello *et al.* (2012), Agnello *et* al. (2015) and Agnello and Sousa (2013) show the importance of asset wealth and asset prices to fiscal policy rules, as well as a countercyclical policy with respect to wealth, within a non-linear framework. There have also been a number of studies that have identified the importance of wealth to the risk premium, including Sousa (2012) and Rocha Armada *et al.* (2014). In particular when wealth to income ratios change, there is a reaction in both the risk premium in stocks and government bonds.

The importance of monetary policy to the economy and its relationship with the financial markets as a whole, underlines the relevance of including asset prices in the Taylor rule model. Studies such as Sousa (2010b, 2014), Castro and Sousa (2012) find that monetary policy changes produce an important wealth effect, facilitating quick adjustments in financial wealth, with a more gradual response by housing wealth. Also Mallick and Sousa (2012) find that in a sample of emerging economies wealth is an important part of the transmission mechanism.

There is also an extensive literature on the importance of asset prices to exchange rate determination, especially stock prices. These studies include the Solnik (1987) study of exchange rates and equity markets and Smith (1992) who develops a portfolio balance model of the exchange rate including stock prices as well as Granger et. al. (2000) who analyse causal relationships between exchange rates and stock prices during the East Asian financial crisis. Overall the results from these studies show changes in stock prices have significant effects on the exchange rate, although there is less use of housing as the wealth effect so far.

The aim of this study is to build on this literature by incorporating wealth effects into the Taylor rule framework. Firstly we estimate this relationship using stock prices and house prices and their wealth equivalents for the US, UK, Australia and Sweden. Secondly we use this model for out-of-sample forecasting of the interest rate. Finally, we use the same Taylor rule model as the basis for a model of the exchange rate, building on recent work in this area by adding wealth effects into the model, this is solely used for out-of-sample forecasting and shown to improve on the model without wealth effects.

3. The Taylor rule Model

The link between the interest rate and macro-fundamentals stems from the central bank's approach to monetary policy, according to the Taylor rule (Taylor, 1993) the simplest approach to monetary policy relates to setting the interest rate in response to changes in inflation and the output gap.

$$i_t^* = \pi_t + \delta(\pi_t - \pi_t^*) + \gamma y_t + r^* \tag{1}$$

where i_t^* is the target for the short-term nominal interest rate, π_t is the inflation rate, π_t^* is the target level of inflation, y_t is the output gap, or percent deviation of actual real GDP from an estimate of its potential level, and r^* is the equilibrium level of the real interest rate. Combining parameters π_t^* and r^* from equation (1) into one constant term $\mu = r^* - \delta\pi^*$. We can derive the following form of the Taylor rule:

$$i_t^* = \mu + \lambda\pi_t + \gamma y_t \tag{2}$$

where $\lambda = 1 + \delta$.

Later, studies by Clarida *et al.* (1998) and Taylor (2001, 2002) suggest that the original Taylor rule should be modified for a small open economy by including the real exchange rate within the interest rate rule.[1] In this spirit, we consider our baseline specification for the monetary policy-makers' interest rate as:

$$i_t^* = \mu + \lambda\pi_t + \gamma y_t + \phi q_t \tag{3}$$

where q_t is the real exchange rate.

In addition to the above baseline specification, this study extends the model through the addition of variables representing wealth effects and asset prices into the baseline equation, as used in other studies such as Semmler and Zhang (2007).

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[1] Central banks in small open economies often set targets for the level of the exchange rate to ensure PPP holds in the long run.

$$i_t^* = \mu + \lambda\pi_t + \gamma y_t + \phi q_t + \beta w_t \quad (4)$$

where w_t is a vector of additional variables representing the wealth effects or asset prices. Another specification considered was the inertial and non-inertial hypothesis, regarding the conduct of monetary policy, whereby a lagged interest rate is usually included in the estimation of the Taylor rule to account for the central bank's inertia and the smooth adjustment of the interest rate to its target value. As a result, the actual observable interest rate i_t adjusts partially towards the target with a degree of inertia as follows:

$$i_t = (1-\rho)i_t^* + \rho i_{t-1} + v_t \quad (5)$$

where ρ denotes the degree of interest rate smoothing and v_t is the error term also known as the interest rate smoothing shock. Substituting (4) into (5) gives the following equation for the actual short-term interest rate:

$$i_t = (1-\rho)(\mu + \lambda\pi_t + \gamma y_t + \beta w_t + \phi q_t) + \rho i_{t-1} + v_t \quad (6)$$

This Takes the U.S. as the benchmark country and equation (6) as the interest rate reaction function for the foreign country. The monetary policy reaction function for the US is the same as equation (6) but $\phi = 0$.

Consider the general form of the model as follows:

$$i_t = \alpha_m + \beta_m X_{m,t} + \eta_{m,t+1} \quad (7)$$

where m represents the specific model being estimated, i_t is the desired interest rate. $X_{m,t}$ contains the economic variables used in the various models m. The specifications considered in this study include:

Model 1: $X_{1,t} \equiv [c \quad \pi_t \quad y_t \quad \tilde{q}_t \quad]$

Model 2: $X_{2,t} \equiv [c \quad \pi_t \quad y_t \quad \tilde{q}_t \quad P_{stock} \quad P_{house}]$

Model 3: $X_{3,t} \equiv [c \quad \pi_t \quad y_t \quad \tilde{q}_t \quad fw \quad hw]$

Model 4: $X_{4,t} \equiv [c \quad \pi_t \quad y_t \quad \tilde{q}_t \quad i_{t-1}\ ]$

Model 5: $X_{5,t} \equiv [c \quad \pi_t \quad y_t \quad \tilde{q}_t \quad i_{t-1} \quad P_{stock} \quad P_{house}]$

Model 6: $X_{6,t} \equiv [c \quad \pi_t \quad y_t \quad \tilde{q}_t \quad i_{t-1} \quad fw \quad hw]$

where P_{stock} and P_{house} are stock prices and house prices and fw and hw are financial wealth and housing wealth respectively.

4 Data

The countries included in this study are the UK, Australia, Sweden and the USA. The first three countries are relatively small, whilst all have strong and highly liquid financial markets. We have used quarterly data from 1979:Q1 to 2008:Q4 for the estimation and forecasting. All variables except the interest rate are in natural logarithms. As in other studies, stock prices and house prices are used to represent the asset prices, with financial wealth and housing wealth to account for the asset wealth. A detailed description of this data can be found in Appendix A.

All the variables, except the financial variables, were obtained from *Thomson DataStream*. We have used the CPI to measure the price level and following Taylor (1993), inflation is measured as the difference in CPI over the previous four quarters. The money market rates are used as the measure of the short-term interest rates. With respect to the exchange rate forecasting, the nominal exchange rate is defined as the U.S. dollar price of foreign currency and is taken to be the end of month exchange rate. The real foreign/USD exchange rate is calculated as the percentage deviation of the nominal exchange rate from the target defined by PPP (i.e. $\tilde{q}_t = s_t - (p_t - p_t^*)$, where p_t and p_t^* are the natural log of the U.S. and the foreign price level is measured by CPI respectively).

Orphanides (2001) has highlighted the importance of using real time data in monetary policy analysis, especially when using output gap measures. Since real output data is revised routinely, so should the output gap estimates be similarly revised, using both actual and potential output. Real time data is based on vintages of data that were actually available to researchers at each point in time (i.e. before data revisions were applied to the data). Since real time data is only available for the U.S. among the countries studied, we have followed Molodtsova and Papell (2009) and used quasi-real time data when measuring the output gap.[2] In this case, current vintage data is used, but the trend at period t is calculated using observations 1 to t. Orphanides and van Norden (2002) looked at the problems of imprecise output gap estimates for the implementation of the Taylor rule and concluded that policy reaction functions estimated with final data might provide misleading results on how policy makers react to the information available to them in real time. Moreover, they have shown that the Taylor rule estimates based on quasi-real time output measures provide a more accurate description of policy than a Taylor rule based on revised data. Studies by Molodtsova, *et al*. (2008) among others highlight the importance of real time data in Taylor rule based exchange rate predictability and stronger evidence of exchange rate predictability has been found in models with quasi-real time data than fully revised data.[3]

For both the Taylor rule and exchange rate studies, real GDP data are used for the output gap estimates. In order to construct the output gap, a trend was estimated based on quasi-real time data. For the first vintage 1979:Q1, the trend is calculated using data from 1975:Q1 to 1978:Q4. For each subsequent vintage, we update the trend by one quarter. For example, the output gap for 1980:1 is the deviation from a trend calculated from 1975:q1 to 1979:4.

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[2] The data itself incorporates revisions, but the trend does not use ex-post observations.

[3] The models were also estimated with revised data, then used for forecasting, although as with Molodstova *et al.* (2008) using real time data and Molodstova and Papell (2009) using quasi-real data, we found evidence of predictability for the US/DM exchange rates with the real time data, but not when using the revised data.

The three leading detrending methods are linear, quadratic and the Hodrick-Prescott (1997) (HP) filter. Results from the study by Nikolsko-Rzhevskyy and Papell (2012) and Nikolsko-Rzhevskyy *et al*. (2014) have already ruled out real-time linear detrending as an appropriate method for constructing the output gap. However, the choice of real-time quadratic and the HP detrended gap requires more analysis. For this reason, we have used two detrending methods, the HP filter and the quadratic detrending approach, both with quasi-real time output gaps. The real time detrended output gaps are shown in figures 1 to 4. In general, we found the results were consistent with Nikolsko-Rzhevskyy and Papell (2012) and Nikolsko-Rzhevskyy *et al*. (2014), as the quadratic output gaps move in the same direction as the HP filtered output gap with the quadratic output gaps always above the HP filtered gaps.[4]

5. Estimation and forecasting of the Taylor rule model

5.1 Estimation of the Taylor rule Model

This section examines the in-sample estimates of the six specifications of the Taylor rule over the entire sample period 1979:Q1 to 2008Q4. The models have been estimated using Dynamic Ordinary least Squares (DOLS), which corrects for the independent variable endogeneity by the inclusion of leads and lags of the first differences of the regressors and for serially correlated

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[4] In the approaches of Nikolsko-Rzhevskyy and Papell (2012) and Nikolsko-Rzhevskyy et al. (2014), Okun's Law was used as benchmark to determine the appropriate real-time output gap measure. Focusing on the U.S. peak unemployment associated with the recessions in the 1970s and 1980s, the constructed "rule-of-thumb" output gaps for Q1 was calculated as -10.5%. Compared to our calculations of the real-time quadratic and HP gaps of -6.25% and -4.31%, the Okun's Law gap is closer to the quadratic gap than to the HP gap.

errors by a GLS procedure.[5] The number of leads and lags used in the estimation were selected according to the Akaike information criterion.

The estimation results are listed in Tables 1, 2, 3 and 4, where we find evidence that including the wealth effects has improved the performance of the Taylor rule models for some countries and some specifications. The results obtained from using the quadratic filter and HP filter give similar results, although the quadratic filter gives slightly better results overall. As with other studies, there is evidence of interest rate inertia and the importance of inflation and the output gap in the determination of interest rate policy. Although the inflation effect and output gap vary in degrees of importance depending on the model specification, as found in other studies such as Qin and Enders (2008). As expected in the simple Taylor rule models without wealth effects, the inflation coefficients are greater than one. This reflects the so-called Taylor principle, which is a necessary condition for an inflation stabilising monetary policy, although this value falls when asset prices and wealth are included in the models.

As with Castro and Sousa (2012) the coefficient signs on the various wealth effects and their significance differ across countries, as does whether asset prices or asset wealth are the most important factor. For the US model, house prices and housing wealth are the dominant wealth factor in determining interest rates, which is a similar result to the findings of Case *et* al. (2005) who found for the US that it is housing wealth, to a greater extent than financial wealth that influences consumption patterns. For the other three countries the influence of both asset classes varies across the country and the model specification. In Sweden, it is the wealth measures which predominate over the asset prices in the case of both smoothing and non-smoothing models. In Australia, the wealth measures again are more important than the asset

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[5] The tables of results for the Taylor rules models excludes the leads and lags for brevity, the full results can be obtained on request.

prices, although this is not particularly robust as they become insignificant when interest rate smoothing is included. In the UK, the effects of asset prices and wealth on interest rates is not strong and with smoothing it becomes insignificant.

These results also illustrate the importance of including financial and housing wealth separately as determinants of interest rates, as found in other studies such as Castro and Sousa (2012). For instance, depending on the country and model specification, housing and equity prices tend to have opposite effects on interest rates. This indicates that central banks find it difficult to stabilise the equity and housing markets simultaneously. This suggests that investors switch funds between the two markets, so when monetary intervention stabilises one market, funds are switched to the other more profitable market, which in turn is destabilised. The greater significance of the wealth measures compared to the asset prices suggests that central banks are more likely to react to shifts in wealth rather than the asset price, possibly due to the importance of asset wealth to the wider macroeconomy, especially consumption. This also supports the view that it is the effect of wealth on price stability rather than asset price stability that concerns the central banks.

These results also confirm the importance of wealth effects on macroeconomic models in general, such as in Case *et al.* (2005), who found that both equity and housing wealth significantly affect consumption, although housing tends to be the dominant effect. This is not surprising given that all the countries used in this study have strong private sector housing markets, where the individual’s housing wealth tends to exceed their wealth in the stock market. This suggests that the monetary authorities could include some measure of wealth either directly or indirectly in their interest rate reaction function, especially housing wealth. However these results suggest that the relationship between monetary policy and asset markets varies across countries, so which form of wealth the authorities monitor will vary, again this finding is apparent in other studies such as Castro and Sousa (2012).

5.2 Forecasting of the Taylor rule Model

In this section, we access the performance of the models in terms of their out-of-sample forecasting. Models with wealth and asset prices are tested against the benchmark model, which is the Taylor rule model without wealth effects (Model 4). To obtain the out-of-sample forecasting, we use rolling regressions with a moving window of 40 quarters (10 years) and produce one quarter ahead forecasting. Over the period from 1989Q1 to 2008Q4, we generate the forecasted policy rule. The forecast is then compared to the actual data, where the initial estimation period is from1979Q1 to 1988Q4. Traditionally, when measuring the forecast performance of a model, the mean square prediction error (MSPE) is the most commonly used criterion for comparing forecasting accuracy of a set of models. In the context of non-nested models, the Diebold and Mariano (1995) and West (1996) MSE-t test (DMW test) are often used to evaluate forecasting performance. McCracken (2007) then developed an out-of-sample F-type test of equal MSE. Both tests work well in evaluating the forecasting performance of non-nested models. However, with nested models, as is the case in this study, the test properties are likely to differ.

Clark and McCracken (2001, 2005) and McCracken (2007) show the distribution of the test statistics are not normally distributed for a pair of forecasts from a nested model. Clark and McCracken (2012) further show that both the distribution of the MSE-t and MSE-F are non-standard when the forecasts are nested under the null. Therefore, using standard normal critical values will result in very poorly sized tests, with too few rejections of the null. This is a problem for our out-of-sample forecasting, since the null is model 4 and the alternative hypotheses are the model with additional wealth effects or asset prices, so the two models are always nested. In order to test for the relative predictive ability of two nested models, Clark and West (2006, 2007) (CW), argue that an adjustment term to centre the statistic around zero are needed in order to get good sized tests. Results from simulations show that the CW test statistic using asymptotically normal critical values results in properly-sized tests for rolling regressions. Clark and McCracken (2001) and Clark and McCracken (2005) construct tests of forecast encompassing for comparison nested models. Furthermore, they show that the F-type test is more powerful than t-type tests of forecast encompassing.

For this study, a number of forecast performance evaluation criteria are used including the CW test, the Clark and McCracken's (2001) encompassing test and the modified Diebold and Mariano (1995) encompassing test, proposed initially by Harvey et al. (1998). Moreover, the DMW test and the McCracken's (2007) equal forecast accuracy test (MSE-F) are provided for comparison purposes. A detailed description of all the methods used in this study are presented in Appendix B.

The fluctuation test, as proposed by Giacomini and Rossi (2010) is applied to investigate possible fluctuations in the relative predictive abilities of the forecast models. Unlike the CW and other tests, which select the model with the best overall forecasting performance, this test focuses on the entire time path of the models' relative performance. This is done by plotting the standardized sample path of the relative measure of local performance (difference in MSFEs), together with the corresponding critical values, indicating that one of the models will have outperformed its competitor at some point, if crossed.

Table 5 presents the one-quarter-ahead out-of-sample forecasts for the Taylor rule compared to the forecasts from a random walk without drift. The overall results suggest evidence of some short-term predictability, especially for the UK, USA and Sweden, with both the asset prices and asset wealth measures outperforming the simple Taylor rule model without the wealth effect. In addition this seems to hold regardless of whether the output gap is produced by the HP filter or quadratic trend, although as in other studies such as Molodtsova *et al*. (1998) the results with the quadratic trend are slightly more significant than the HP filter. The forecast performance measures tend to produce similar results overall, except as expected the MSE-t and the MSE-F measures, which fail to provide support for the wealth augmented models outperforming the standard model. As noted previously this could be due to their failure to account for the nested nature of the models being tested.

The standard tests of forecasting performance provide evidence of an overall better predictability from using the wealth effects models. However, this does not guarantee its robustness at each point in time. Figure 5 shows the results of the fluctuation tests with the Taylor rule model, which assesses the forecast stability over time. Since the values of the statistics are not always below the critical values, we reject the null hypothesis of equal predictive ability at each point in time, although this rejection is limited to short periods corresponding to excessive volatility in the economy, such as the Swedish banking crisis during the early 1990s, which directly impacted on monetary policy.

6. Out of sample Taylor rule based exchange rate predictability

6.1 Taylor rule fundamentals

Out-of-sample forecasting is a popular tool for selecting among a set of alternative exchange rate specifications. In this section we use the wealth augmented Taylor rule models, to develop three wealth augmented models of the USD/foreign nominal exchange rate. The first specification assumes both the U.S. and foreign monetary authorities determine their interest rate according to a Taylor rule, where the nominal interest rate responds to inflation, the output gap, real exchange rate and the lagged interest rate. The second and third specifications include a vector of additional variables w_t which, represent asset prices and wealth composition respectively.

In order to test the out-of-sample predictability, we use a similar approach to Molodtsova and Papell (2009). By subtracting the Taylor rule for the foreign country from that of the U.S., an exchange rate forecasting equation with Taylor rule fundamentals can subsequently be derived. Let ~ denote variables for the foreign country, by subtracting the Taylor rule equation for the foreign country from that of the domestic country, in this case the US, we get:

$$\begin{aligned} i_t - \tilde{i}_t = \psi + (\psi_{u\pi}\pi_t - \psi_{f\pi}\tilde{\pi}_t) + (\psi_{uy}y_t - \psi_{fy}\tilde{y}_t) + (\psi_{uw}w_t \\ - \psi_{fw}\widetilde{w}_t) - \psi_q\tilde{q}_t + \rho_u i_{t-1} - \rho_f\tilde{i}_{t-1} + \eta_t \end{aligned} \tag{8}$$

Where u and f are coefficients for the U.S. and the foreign country respectively. ψ is a constant, $\psi_\pi = \lambda(1-\rho)$, $\psi_y = \gamma(1-\rho)$ and $\psi_w = \beta(1- \ \rho)$ for both countries, and $\psi_q = \ \phi(1-\rho)$ for the foreign country.

In order to derive the exchange rate equation, the simplest and most direct way is to assume the expected rate of exchange rate depreciation is proportional to the interest rate differential or uncovered interest parity (UIP):

$$E(\Delta s_{t+1}) = \beta(i_t - \tilde{i}_t) \tag{9}$$

where Δs_{t+1} is the logarithmic difference of the nominal exchange rate, specified as the price of the home currency in terms of the foreign currency, and E denote the expectations operator. Substituting (8) into (9), we have the following standard Taylor rule exchange rate forecasting equation as in Molodstova and Papell (2009):

$$\begin{aligned} \Delta s_{t+1} = \delta + \delta_{u\pi}\pi_t - \delta_{f\pi}\tilde{\pi}_t + \delta_{uy}y_t - \delta_{fy}\tilde{y}_t + \delta_{uw}w_t - \delta_{fw}\widetilde{w}_t \\ - \delta_q\tilde{q}_t + \delta_{ui}i_{t-1} - \delta_{fi}\tilde{i}_{t-1} + \eta_t \end{aligned} \tag{10}$$

where s_t is the natural log of the U.S. nominal exchange rate, defined as the US dollar per unit of foreign currency, so that an increase in s_t implies a depreciation of the US dollar. The above model is then augmented with the asset prices and wealth as in the earlier Taylor rule models (1) to (6), derived in section 3 earlier.

Based on the studies of Molodtsova and Papell (2009) and Molodtsova and Ince (2008) and considering the lack of empirical support for UIP,[6] there is no reason to believe that the coefficients in equation (10) will match the coefficients implied by the estimated Taylor rule exchange rate model. Since we do not know the extent to which changes in the interest rate differential affect the exchange rate, we estimate our forecasting equations without imposing any restrictions on the signs and magnitudes of the coefficients.

6.2 Tests of equal predictability

In line with previous work, we use the random walk model as one of our benchmark naïve models.[7] In addition, we will also use the corresponding models without wealth effects as a second benchmark, as they provide useful information on whether the wealth effect improves our forecasting performance.

Benchmark one: Driftless Random walk

$$\Delta s_{t+1} = 0 \tag{11}$$

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[6] Kearns and Manners' (2006) suggest that although the UIP condition has been argued by many to be an empirical failure (e.g. Chinn, 2006), it might work reasonably well in a small economy, such as the three of those used here, as changes in interest rates in small economies are unlikely to have an impact on foreign interest rates and hence affect the exchange rate. Moreover, UIP connects expected changes in exchange rates to interest differentials, which has been proven to be an important and useful transmission channel connecting exchange rate changes endogenously to monetary policy (Molodtsova & Papell, 2009).

[7] We choose the random walk with no drift to be one of the benchmark models because according to Meese and Rogoff (1983a, b) it is the toughest benchmark to beat.

Benchmark two: Taylor rule exchange rate model without wealth effects.

$$\begin{aligned}\Delta s_{t+1} = \delta + \delta_{u\pi}\pi_t - \delta_{f\pi}\tilde{\pi}_t + \delta_{uy}y_t - \delta_{fy}\tilde{y}_t - \delta_q\tilde{q}_t + \delta_{ui}i_{t-1} \\ - \delta_{fi}\tilde{\imath}_{t-1} + \eta_t\end{aligned} \tag{12}$$

Using the same approach as in the earlier forecasting of the wealth augmented Taylor rule model, the rolling regressions have a moving window of 40 quarters (10 years). The forecasts are conducted over the period from 1989Q1 to 2008Q4, with the initial estimation period from1979Q1 to 1988Q4.

Tables 9, 10 and 11 contain the results of the out-of-sample forecasts for the Taylor rule based exchange rate models which tend to follow the results of the forecasts with the earlier Taylor rule overall. The upper section of the tables refers to the test for predictability compared to the random walk for all six models and there is clear evidence that the models all outperform the random walk. The second and third section of the results tables are for the wealth augmented models against the models without the wealth effect. Again there is evidence that the model with the wealth effect forecasts better than the one without. As with the earlier Taylor rule, there is little difference in the results depending on whether the quadratic or HP filter is used to produce the output gap, although the quadratic filter is slightly better, especially for Sweden.

The specifications incorporating asset prices include models 2 and 5, whilst models 3 and 6 contain the wealth effects. As with the forecasts of the Taylor rules, there is little difference in the performance of the two types of wealth measure. The only exception is Australia, where the asset price specifications outperform the asset wealth models. A possible explanation for this could be that Australia is a commodity based economy, where movements in commodity prices influence the exchange rate of Australia to a greater extent than non-resource rich economies, as in Chen and Rogoff (2003). The movements in commodity prices are likely to be reflected in changes to asset prices more quickly than asset wealth.

As expected the results tend to be sensitive to the test statistics used to assess their performance, although the null hypothesis is rejected in nearly all cases, the MSE-t and the MSE-F statistics fail to pick up any significant difference. This could again be due to their unsuitability with the nested models used here. Although there are some exceptions for the MSE-t statistic for all the exchange rates, especially Australia. Finally, Figure 6 reports the fluctuation test results of the forecasts of the exchange rate with the asset price models. The values of the statistics for the wealth composition models are similar, so are not reported. We conclude that the Taylor rule exchange rate models with wealth effects do not uniformly outperform the standard Taylor rule exchange rate models in exchange rate forecasting, although again this failure is limited to some very short periods of excessive volatility in the exchange rate, such as the European Exchange rate Mechanism (ERM) crisis in the UK during September 1992.

7. Conclusions

Using both the Taylor rule model and the Taylor rule based exchange rate model, where both have been augmented with various wealth effects, our overall results show that the addition of the wealth effect has improved the performance of both models in terms of out-of-sample forecasting. However the estimates of the wealth augmented Taylor rule models vary across countries and depend on whether house prices or stock prices measure the wealth effect, as with other studies housing tends to be the most significant effect. In addition the results are sensitive to the form the wealth is in, with better results coming from the models with asset wealth rather than the asset prices.

As with much of the literature the best test of the models is the out-of-sample forecasts, relative to the random walk. We found that the out-of-sample forecasts of the wealth augmented Taylor rule model tend to outperform the standard Taylor rule based model without the wealth effect and also the random walk. The same is the case with the exchange rate models, where the wealth augmented Taylor rule model outperforms the random walk and the standard Taylor rule exchange rate model in out-of-sample forecasts. As with other studies we found the quadratic filtered output gap performs slightly better than the HP filter and these findings support those of other studies showing the Taylor rule model with quasi- real time (real time) data can produce better forecasts than the random walk. Overall the inclusion of wealth effects into this model provides evidence of their importance in determining exchange rates, which has been found previously in other specifications of wealth augmented exchange rate models.

The policy implications from these results are the need for greater emphasis on the role of wealth effects in determining monetary policy, although it varies with how the wealth is measured and across countries. When assessing and predicting movements in the main monetary instruments, the inclusion of a measure of wealth significantly improves the accuracy of the predictions, facilitating more effective management of the economy by the authorities. An area for future research could explore the relevance of alternative measures of wealth into these models, such as measures of combined financial wealth, as the data becomes more available.

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Table 1. Estimation of the Taylor rule for the UK

UK

Output gap: HP filter

variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
c	9.030**	11.891**	32.022**	1.802**	2.422	5.608
π_t	0.977**	0.904**	0.386**	0.163**	0.219	0.091
y_t	1.179**	1.221**	1.481**	0.534**	0.530**	0.673**
$\tilde{q}_t$	-8.872**	-3.985	-3.938	-2.232*	-1.923	-1.941
i_{t-1}				0.840**	0.778**	0.808**
P_{stock}		0.727			0.173	
P_{house}		-2.422*			-0.415	
fw_t			-3.113*			-0.640
hw_t			-0.165			0.151
$Adj. R^2$	0.718	0.803	0.780	0.944	0.940	0.945

Output gap: Quadratic trended

variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
c	8.939**	13.379**	37.083*	1.611*	1.708	4.616
π_t	1.124**	1.038**	0.311	0.227**	0.389**	0.234*
y_t	0.586**	0.698**	1.482*	0.174**	0.231**	0.257**
$\tilde{q}_t$	-9.606**	-7.289**	-5.081	-2.001	-2.849	-3.117
i_{t-1}				0.823	0.713	0.764**
P_{stock}		0.536			0.338	
P_{house}		-2.088**			-0.417	
fw_t			-3.222*			-0.282
hw_t			-0.650			0.002
$Adj. R^2$	0.761	0.856	0.771	0.939	0.939	0.939

Notes: The table shows coefficients of the variables over the entire sample period. Models are estimated by Dynamic OLS where standard errors have been Newey-West corrected. Along with the fundamentals in levels, the first difference as well as the first differences with up to 2 period lags were considered. Here, due to a lack of space only the coefficients of the fundamentals in levels are reported. ** and * denote significance at 1% and 5% levels, respectively.

Table 2. Estimation of the Taylor rule for Sweden

<table>
<tr><th colspan="7">Sweden</th></tr>
<tr><th colspan="7">Output gap: HP filter</th></tr>
<tr><th>variables</th><th>Model 1</th><th>Model 2</th><th>Model 3</th><th>Model 4</th><th>Model 5</th><th>Model 6</th></tr>
<tr><td>c</td><td>1.483</td><td>21.360*</td><td>31.298**</td><td>2.759</td><td>16.270*</td><td>31.600**</td></tr>
<tr><td>π_t</td><td>1.072**</td><td>-0.082*</td><td>-0.429*</td><td>0.368*</td><td>-0.187</td><td>-0.431*</td></tr>
<tr><td>y_t</td><td>-0.431</td><td>1.261**</td><td>0.499</td><td>0.065</td><td>0.981*</td><td>0.502</td></tr>
<tr><td>$\tilde{q}_t$</td><td>1.019</td><td>6.068*</td><td>-1.626</td><td>-0.664</td><td>3.089</td><td>-1.618</td></tr>
<tr><td>i_{t-1}</td><td></td><td></td><td></td><td>0.623**</td><td>0.391**</td><td>-0.014</td></tr>
<tr><td>P_{stock}</td><td></td><td>-4.851**</td><td></td><td></td><td>-3.505*</td><td></td></tr>
<tr><td>P_{house}</td><td></td><td>2.327</td><td></td><td></td><td>1.935</td><td></td></tr>
<tr><td>fw_t</td><td></td><td></td><td>-9.493**</td><td></td><td></td><td>-9.611**</td></tr>
<tr><td>hw_t</td><td></td><td></td><td>7.929**</td><td></td><td></td><td>8.029**</td></tr>
<tr><td>$Adj. R^2$</td><td>0.524</td><td>0.681</td><td>0.779</td><td>0.678</td><td>0.719</td><td>0.776</td></tr>
<tr><th colspan="7">Output gap: Quadratic trended</th></tr>
<tr><th>variables</th><th>Model 1</th><th>Model 2</th><th>Model 3</th><th>Model 4</th><th>Model 5</th><th>Model 6</th></tr>
<tr><td>c</td><td>0.336</td><td>37.027**</td><td>41.118**</td><td>2.631</td><td>29.658**</td><td>41.596**</td></tr>
<tr><td>π_t</td><td>1.092**</td><td>0.048</td><td>-0.376*</td><td>0.392**</td><td>-0.008</td><td>0.378*</td></tr>
<tr><td>y_t</td><td>0.158</td><td>0.463**</td><td>0.040</td><td>-0.015</td><td>0.359*</td><td>0.004</td></tr>
<tr><td>$\tilde{q}_t$</td><td>1.565</td><td>2.152</td><td>-1.052</td><td>-0.576</td><td>0.621</td><td>-1.033</td></tr>
<tr><td>i_{t-1}</td><td></td><td></td><td></td><td>0.607**</td><td>0.272</td><td>-0.014</td></tr>
<tr><td>P_{stock}</td><td></td><td>-1.635</td><td></td><td></td><td>-1.209</td><td></td></tr>
<tr><td>P_{house}</td><td></td><td>-3.803</td><td></td><td></td><td>-2.842</td><td></td></tr>
<tr><td>fw_t</td><td></td><td></td><td>-8.288**</td><td></td><td></td><td>-8.386**</td></tr>
<tr><td>hw_t</td><td></td><td></td><td>5.958**</td><td></td><td></td><td>6.025**</td></tr>
<tr><td>$Adj. R^2$</td><td>0.534</td><td>0.712</td><td>0.774</td><td>0.678</td><td>0.725</td><td>0.771</td></tr>
</table>

Notes: The table shows coefficients of the variables over the entire sample period. Models are estimated by Dynamic OLS where standard errors have been Newey-West corrected. Along with the fundamentals in levels, the first difference as well as the first differences with up to 1 period lags were considered. Here, due to a lack of space only the coefficients of the fundamentals in levels are reported. ** and * denote significance at 1% and 5% levels, respectively.

Table 3. Estimation of the Taylor Rule for Australia

Australia						
Output gap: HP filter						
variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
c	4.434**	17.735**	-1.215	0.563	5.661*	2.179
π_t	1.129**	0.861**	1.025**	0.138**	0.836	0.092
y_t	0.568*	0.884**	0.607**	0.296**	0.346**	0.242*
$\tilde{q}_t$	2.135	2.998	4.333*	0.558	0.872	0.466
i_{t-1}				0.886**	0.878**	0.880**
P_{stock}		-1.042			-1.133	
P_{house}		-1.050			0.944	
fw_t			10.984**			-0.245
hw_t			-9.130**			-0.011
$Adj. R^2$	0.682	0.777	0.759	0.947	0.957	0.946
Output gap: Quadratic trended						
variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
c	4.866**	21.209**	0.860	0.815*	5.999*	2.096
π_t	1.140**	0.824**	0.988**	0.139**	0.088	0.092
y_t	0.281	0.582**	0.362*	0.126*	0.151*	0.079
$\tilde{q}_t$	3.483	4.933*	5.556**	1.320	1.757*	1.026
i_{t-1}				0.887**	0.883**	0.889**
P_{stock}		-1.353			-1.156	
P_{house}		-1.072			0.982	
fw_t			10.958**			-0.330
hw_t			-9.308**			0.090
$Adj. R^2$	0.675	0.781	0.757	0.945	0.955	0.945

Notes: The table shows coefficients of the variables over the entire sample period. Models are estimated by Dynamic OLS where standard errors have been Newey-West corrected. Along with the fundamentals in levels, the first difference as well as the first differences with up to 1 period lags were considered. Here, due to a lack of space only the coefficients of the fundamentals in levels are reported. ** and * denote significance at 1% and 5% levels, respectively.

Table 4. Estimation of the Taylor rule for the USA

U.S.						
Output gap: HP filter						
variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
c	1.489**	26.497**	34.393**	-0.205	3.487	3.036
π_t	1.232**	1.075**	0.744**	0.225**	0.459**	0.226**
y_t	0.430	0.472**	0.510**	0.141	0.168	0.144
i_{t-1}				0.889**	0.779**	0.842**
P_{stock}		1.092*			0.433	
P_{house}		-6.628**			-1.414*	
fw_t			0.309			0.258
hw_t			-3.971**			-0.660
Adj. R^2	0.706	0.869	0.825	0.956	0.969	0.958
Output gap: Quadratic trended						
variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
c	1.059**	23.927**	32.017**	-0.269	2.107	2.157
π_t	1.366**	1.107**	0.856**	0.294**	0.523**	0.283**
y_t	0.061	0.396**	0.317**	0.050	0.077	0.079
i_{t-1}				0.861**	0.766**	0.828
P_{stock}		0.198			0.229	
P_{house}		-4.812**			-0.858	
fw_t			0.021			0.141
hw_t			-3.393**			-0.431
Adj. R^2	0.743	0.879	0.833	0.958	0.969	0.958

Notes: The table shows coefficients of the variables over the entire sample period. Models are estimated by Dynamic OLS where standard errors have been Newey-West corrected. Along with the fundamentals in levels, the first difference as well as the first differences with up to 2 period lags were considered. Here, for lack of space only the coefficients of the fundamentals in levels are reported. ** and * denote significance at 1% and 5% levels, respectively.

Table 5. Forecasts of the Taylor rule for the UK

UK						
	MSPE		**CW**		**MSE-t**	
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 4	0.729	0.670	-	-		
Model 5	0.802	0.644	1.463*	1.528*	-0.489	-0.329
Model 6	0.613	0.599	1.826**	1.641*	0.136**	-0.104*
	MSE-F		**ENC-F**		**ENC-t**	
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 5	-10.422	-6.095	32.909***	27.900***	2.404***	2.469***
Model 6	2.612**	-1.628	25.730***	16.058***	2.579***	1.946**

Notes: Significance levels at 90%, 95%, and 99% are denoted by one, two, and three stars, respectively. MSPE is between respective Taylor rule model and actual interest rate. CW, MSE-t, MSE-F, ENC-F and ENC-t are test values relative to the benchmark Taylor rule without wealth effects model (Model 4). For CW statistics, the null hypothesis is rejected if the statistic is greater than +1.282 (for a one side 0.10 test) or +1.645 (for a one side 0.05 tests). The critical value for MSE-t, MSE-F, ENC-F and ENC-t are obtain from Clark and McCracken (2001) and McCracken (2004)

Table 6. Forecasts of the Taylor rule for Sweden

Sweden						
	MSPE		**CW**		**MSE-t**	
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 4	0.808	0.888	-	-		
Model 5	0.670	0.925	2.431**	2.001**	1.295***	0.739***
Model 6	0.726	0.933	2.065**	1.630*	0.341**	-0.264
	MSE-F		**ENC-F**		**ENC-t**	
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 5	24.152***	10.235***	42.182***	24.219***	2.872***	2.824***
Model 6	4.395***	-3.079	13.272***	6.591***	1.876**	1.071

Note: see notes on table 5.

Table 7. Forecasts of the Taylor rule for Australia

Australian						
	MSPE		**CW**		**MSE-t**	
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 4	0.404	0.414	-	-		
Model 5	0.417	0.333	1.213	3.059**	-1.538	-0.927
Model 6	0.609	0.456	0.341	1.448*	-2.340	-1.257
	MSE-F		**ENC-F**		**ENC-t**	
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 5	-13.116	-8.906	13.969***	25.864***	1.783**	3.429***
Model 6	-31.265	-21.485	5.373**	20.110***	0.769	2.339***

Note: see notes on table 5.

Table 8. Forecasts of the Taylor rule for the US

US						
	MSPE		**CW**		**MSE-t**	
	HP filter	***Quadratic detrended***	***HP filter***	***Quadratic detrended***	***HP filter***	***Quadratic detrended***
Model 4	0.329	0.396	-	-		
Model 5	0.311	0.433	1.676**	1.549*	-0.630	-0.407
Model 6	0.389	0.402	1.552*	2.502**	-1.472	-0.453
	MSE-F		**ENC-F**		**ENC-t**	
	HP filter	***Quadratic detrended***	***HP filter***	***Quadratic detrended***	***HP filter***	***Quadratic detrended***
Model 5	-9.154	-6.953	23.119***	30.838***	2.395***	3.156***
Model 6	-17.559	-6.177	17.291***	39.462***	2.241***	3.740***

Note: see notes on table 5.

Table 9. Forecasts of the UK/US exchange rate

Benchmark: Random Walk										
	CW		**ENC-F**		**ENC-t**		**MSE-F**		**MSE-t**	
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 1	2.430**	3.120**	9.922***	12.067***	1.681**	1.965**	-11.449	-11.935	-1.028	-0.970
Model 2	3.542**	3.077**	26.251***	24.240***	2.877***	2.425***	-21.540	-25.954	-1.292	-1.480*
Model 3	3.154**	3.191**	21.163***	16.579***	2.734***	2.522***	-30.707	-39.434	-2.153	-2.870
Model 4	3.089**	3.219**	16.364***	16.101***	2.449***	2.428***	-13.116	-21.128	-0.972	-1.447
Model 5	3.455**	3.069**	23.758***	18.493***	2.429***	1.874**	-30.002	-38.295	-1.562	-1.624
Model 6	3.365**	3.275**	21.400***	19.435***	2.844***	2.727***	-35.194	-39.902	-2.383	-2.802
Benchmark: Model 1										
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 2	3.084**	2.218**	24.997***	25.518***	2.925***	2.557***	-11.776	-16.478	-0.741	-0.851
Model 3	2.715**	2.016**	15.077***	13.717***	2.103**	2.078**	-22.474	-32.321	-1.546	-2.256
Benchmark: Model 4										
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 5	2.045**	2.149**	17.188***	18.126***	1.893**	2.104**	-20.197	-23.327	-1.092	-0.955
Model 6	1.720**	1.905**	11.176***	13.925***	1.547**	2.228***	-26.407	-25.512	-1.890	-1.837

Note: CW, MSE-t, MSE-F, ENC-F and ENC-t are test values relative to the benchmark. Significance levels at 90%, 95%, and 99% are denoted by one, two, and three stars, respectively. For CW statistics, the null hypothesis is rejected if the statistic is greater than +1.282 (for a one side 0.10 test) or +1.645 (for a one side 0.05 tests). The critical value for MSE-t, MSE-F, ENC-F and ENC-t are obtain from Clark and McCracken (2001) and McCracken (2004). Random walk MSPE: 0.00221.

Table 10. Forecasts of the Swedish /US exchange rate

Benchmark: Random Walk										
	CW		**ENC-F**		**ENC-t**		**MSE-F**		**MSE-t**	
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 1	1.991**	2.802**	7.073**	11.337***	1.733**	2.645***	-9.409	-13.634	-1.119	-1.489
Model 2	3.209**	2.608**	27.315***	36.100***	3.434***	2.820***	-25.806	-26.126	-0.959*	-0.786**
Model 3	3.941**	3.941**	30.077***	28.748***	3.880***	3.557***	-35.630	-32.841	-1.471	-1.331
Model 4	2.684**	3.417**	9.355**	14.650***	2.118**	2.868***	-17.804	-20.195	-2.038	-1.945
Model 5	3.047**	2.521**	22.656***	32.070***	3.268***	2.642***	-32.965	-31.484	-1.293*	-0.981**
Model 6	4.261**	3.814**	22.954***	20.978***	3.796***	3.587***	-46.663	-47.778	-1.641	-1.550
Benchmark: Model 1										
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 2	2.787**	2.539**	21.254***	34.933***	2.227**	2.470***	-18.583	-15.057	-0.707	-0.460*
Model 3	2.833**	2.680**	21.693***	26.257***	2.316***	2.978***	-29.716	-23.152	-1.253	-0.971
Benchmark: Model 4										
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 5	2.100**	2.509**	22.297***	34.816***	2.627***	2.348***	-19.501	-15.101	-0.769	-0.486*
Model 6	2.266**	2.622**	18.511***	16.269***	2.473***	2.567***	-37.119	-36.897	-1.311	-1.209

Note: CW, MSE-t, MSE-F, ENC-F and ENC-t are test values relative to the benchmark. Significance levels at 90%, 95%, and 99% are denoted by one, two, and three stars, respectively. For CW statistics, the null hypothesis is rejected if the statistic is greater than +1.282 (for a one side 0.10 test) or +1.645 (for a one side 0.05 tests). The critical value for MSE-t, MSE-F, ENC-F and ENC-t are obtain from Clark and McCracken (2001) and McCracken (2004). Random walk MSPE 0.00392.

Table 11. Forecasts of the Australia /US exchange rate

Benchmark: Random Walk										
	CW		**ENC-F**		**ENC-t**		**MSE-F**		**MSE-t**	
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 1	3.089**	3.226**	14.408***	12.333***	2.180***	2.199***	-3.650*	-15.018	-0.307**	-1.572
Model 2	3.451**	3.112**	30.951***	25.539***	2.027**	2.002**	-15.103	-17.983	-0.650**	-0.812**
Model 3	1.567*	1.289*	7.964**	6.181*	1.771**	1.640**	-43.586	-44.083	-1.156	-1.237
Model 4	3.045**	3.181**	22.315***	22.084***	2.597**	2.861***	-0.649***	-7.384*	-0.043**	-0.621**
Model 5	3.527**	3.350**	38.494***	35.970***	2.589**	2.658**	-15.395	-15.863	-0.726**	-0.706**
Model 6	1.076	0.954	4.795	3.923	1.459*	1.339*	-61.650	-61.641	-1.090	-1.121**
Benchmark: Model 1										
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 2	1.662*	2.255**	18.042***	17.626***	1.693**	1.717**	-12.001	-3.650	-0.753	-0.197**
Model 3	0.505	0.403	4.403*	4.271*	0.923	0.843	-41.845	-35.782	-1.131	-1.013
Benchmark: Model 4										
	HP filter	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*	*HP filter*	*Quadratic detrended*
Model 5	1.512*	1.876**	18.948***	18.117***	2.262***	2.029**	-14.867	-9.341	-1.331	-0.643
Model 6	0.001	0.234	1.876	0.653	0.495	0.154	-61.500	-59.775	-1.091	-1.090

Note: CW, MSE-t, MSE-F, ENC-F and ENC-t are test values relative to the benchmark. Significance levels at 90%, 95%, and 99% are denoted by one, two, and three stars, respectively. For CW statistics, the null hypothesis is rejected if the statistic is greater than +1.282 (for a one side 0.10 test) or +1.645 (for a one side 0.05 tests). The critical value for MSE-t, MSE-F, ENC-F and ENC-t are obtain from Clark and McCracken (2001) and McCracken (2004). Random walk MSPE 0.00362.

Appendix A: Wealth data

The UK

Gross housing wealth is defined as the housing wealth of households and non-profit organizations. The source is the United Kingdom National Accounts - The Blue Book. The data are measured in millions of pounds. Financial wealth is defined as the net financial wealth of households and non-profit organizations, the data is obtained from Table A64 in the UK Economic Accounts, measured in millions of pounds. Quarterly data was estimated by linear interpolation. Stock prices are quarterly closing prices of the FTSE All Share Price Index. The house prices are indices from Oxford economics.

Australia:

Net Financial Wealth: We use quarterly data from 1988:Q4 onward from ABS Cat No 5232.0 and annual data from RBA Occasional Paper No 8 before this date. Household gross non-financial wealth: quarterly data from 1988:Q4 onward from ABS Cat No 5232.0 and annual data from RBA Occasional Paper No 8 before this date. All data measured in billions of Australian dollars. Quarterly data were estimated by linear interpolation. Stock prices are quarterly closing prices of the ASX All Ordinaries 1971. The house prices are the indices from Oxford economics.

Sweden:

Net household financial wealth data is the difference between total household financial assets and total financial liabilities (both including NPISH) and are taken from the FA (financial account) of SCB. The gross housing wealth is the value of housing stock, based on the tax assessment value of owned permanent and seasonal homes (SCB, 2004) multiplied by the purchase-price-coefficient (KB) of each type. The quarterly purchase-to-assessed value coefficients were available only after 1998q1. Quarterly data before 1998 were estimated by linear interpolation. All data are measured in Millions of Swedish Krona. Stock prices are the quarterly closing prices of the OMX Stockholm 30 and OMX Stockholm. House prices are the indices taken from Oxford economics.

US:

Financial wealth is defined as the sum of financial assets minus financial liabilities. Housing wealth is defined as the value of real estate held by households minus home mortgages. The source is the Board of Governors of the Federal Reserve System, Flow of Funds Accounts, Table B.100. Data are quarterly, measured in billions of dollars, and expressed in logarithmic form. Stock prices are quarterly closing prices of the Standard &Poor 500 Composition Index. House prices are the indices from Oxford economics.

Appendix B: Forecasting Techniques

Let $\hat{u}_{1,t+1}$ and $\hat{u}_{2,t+1}$ be the 1 step ahead forecast errors from model 1 and 2 respectively. P denote for the number of forecasts.

1). Tests of equal forecast accuracy

Let $d_{t+1} = \hat{u}_{1,t+1}^2 - \hat{u}_{2,t+1}^2$ and $\bar{d} = P^{-1} \sum_t d_t = MSE_1 - MSE_2$

- Diebold and Mariano (1995) and West (1996) test:

$$MSE - T = P^{1/2} \frac{P^{-1} \sum_t \left(\hat{u}_{1,t+1}^2 - \hat{u}_{2,t+1}^2 \right)}{\sqrt{P^{-1} \sum_t \left(\hat{u}_{1,t+1}^2 - \hat{u}_{2,t+1}^2 \right) - \bar{d}^2}}$$

- The McCracken (2006) equal forecasting accuracy test:

$$MSE - F = P \times \frac{P^{-1} \sum_t \left(\hat{u}_{1,t+1}^2 - \hat{u}_{2,t+1}^2 \right)}{\sqrt{P^{-1} \sum_t \hat{u}_{2,t+1}^2}}$$

2). Tests of forecast encompassing

Let $c_{t+1} = \hat{u}_{1,t+1} \left(\hat{u}_{1,t+1} - \hat{u}_{2,t+1} \right)$ and $\bar{c} = P^{-1} \sum_t c_t$

- The modified DM (1995) encompassing test (known as ENC-t in table) is the Diebold and Mariano (1995) t-statistic modified by Harvey et al. (1998):

$$ENC - T = P^{1/2} \frac{P^{-1} \sum_t \left(\hat{u}_{1,t+1}^2 - \hat{u}_{1,t+1} \cdot \hat{u}_{2,t+1} \right)}{\sqrt{P^{-1} \sum_t \left(\hat{u}_{1,t+1}^2 - \hat{u}_{1,t+1} \cdot \hat{u}_{2,t+1} \right) - \bar{c}^2}}$$

- The Clark and McCracken(2001) encompassing test

$$ENC - F = P \times \frac{P^{-1} \sum_t \left(\hat{u}_{1,t+1}^2 - \hat{u}_{1,t+1} \cdot \hat{u}_{2,t+1} \right)}{\sqrt{P^{-1} \sum_t \hat{u}_{2,t+1}^2}}$$