Taylor Rules and the Euro

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Abstract

This paper uses real-time data to analyze whether the variables that normally enter central banks' interest-rate-setting rules, which we call Taylor rule fundamentals, can provide evidence of out-of-sample predictability for the United States Dollar/Euro exchange rate from the inception of the Euro in 1999 to the end of 2007. The major result of the paper is that the null hypothesis of no predictability can be rejected against an alternative hypothesis of predictability with Taylor rule fundamentals for a wide variety of specifications that include inflation and a measure of real economic activity in the forecasting regression. We also present less formal evidence that, with real-time data, the Taylor rule provides a better description of ECB than of Fed policy during this period. While the evidence of predictability is only found for specifications that do not include the real exchange rate in the forecasting regression, the results are robust to whether or not the coefficients on inflation and the real economic activity measure are constrained to be the same for the U.S. and the Euro Area and to whether or not there is interest rate smoothing. The evidence of predictability is stronger for real-time than for revised data, about the same with inflation forecasts as with inflation rates, and weakens if output gap growth is included in the forecasting regression. Bad news about inflation and good news about real economic activity both lead to out-of-sample predictability through forecasted exchange rate appreciation.

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1. Introduction

The behavior of exchange rates between Europe and the United States, either via multiple currencies until 1999 or via the euro/dollar exchange rate thereafter, has been one of the most studied topics in international economics. The results of this research, however, have been less than stellar. The inability to connect exchange rates with macroeconomic fundamentals, characterized as the "exchange rate disconnect puzzle," has produced pessimism regarding the usefulness of empirical exchange rate models and focused attention on unquantifiable speculative and psychological factors.

A major contributing factor to this exchange rate pessimism has been the inability of empirical exchange rate models, starting with the seminal paper of Meese and Rogoff (1983), to forecast nominal exchange rates out-of-sample better than a naïve no change, or random walk, forecast. While Mark (1995) provided hope that the models would forecast better at long horizons, more recent work such as Cheung, Chinn, and Pascual (2006) concludes that no model consistently does better than a random walk.

This literature, however, still employs the empirical exchange rate models of the 1970s used by Meese and Rogoff. A money market equilibrium equation, or LM curve, for the foreign country is subtracted from a similar equation for the domestic country, producing an equation with the interest differential on the left-hand-side and money supply, income, and price level differentials on the right-hand-side. Using Uncovered Interest Rate Parity (UIRP) and long-run Purchasing Power Parity (PPP), and solving expectations forward, a monetary exchange rate model is derived which can be used for out-of-sample forecasting. Alternatively, the two building-blocks of the monetary model, UIRP and PPP, can be used to derive forecasting equations.

The monetary exchange rate model, however, does not reflect how monetary policy is currently conducted or evaluated. Starting with Taylor (1993), the interest rate reaction function known as the Taylor rule, where the nominal interest rate responds to the inflation rate, the difference between inflation and its target, the output gap, the equilibrium real interest rate, and (sometimes) the lagged interest rate and the real exchange rate, has become the dominant method for evaluating monetary policy.[1] Following Clarida, Gali, and Gertler (1998), (hereafter CGG), Taylor rules have been estimated for a number of countries and time periods.

The evolution of monetary policy evaluation from LM curves and money supply reaction functions to Taylor rules has influenced exchange rate modeling. Clarida, Gali, and Gertler (2002) and Clarida (2007) investigate the derivation and implications of a two-country optimizing model with an open economy IS curve, Phillips curve, and Taylor rule. Engel and West (2006), Mark (2007), and Engel, Mark, and West (2007) have examined the empirical performance of Taylor-rule based exchange rate models.

A major focus of Taylor rule estimation, pioneered by Orphanides (2001), is the use of real-time data that reflects the information available to central banks when they make their interest-rate-setting decisions.

[1] Asso, Kahn, and Leeson (2007) examine the intellectual history of the Taylor rule and its influence on macroeconomic research and monetary policy.

Interest rate reaction functions using real-time data have been estimated by Orphanides (2003, 2004) and Rudebusch (2006) for the United States, Nelson (2003) for the United Kingdom, Clausen and Meier (2005) and Gerberding, Worms, and Seitz (2005) for Germany, and Sauer and Sturm (2007), Gerdesmeier and Roffia (2004), Gorter, Jacobs, and de Haan (2007), and Sturm and Wollmershauser (2008) for the Euro Area.

Although the argument for using real-time data seems at least as compelling for exchange rate forecasting as for Taylor rule modeling, virtually all existent literature on exchange rate predictability uses fully revised data to assess the out-of-sample performance of empirical exchange rate models. The first, and until recently only, paper to use real-time data to evaluate nominal exchange rate predictability is Faust, Rogers and Wright (2003). They examine the predictive ability of Mark's (1995) monetary model using real-time data for Japan, Germany, Switzerland and Canada vis-à-vis the U.S. dollar and conclude that, while the models consistently perform better using real-time data than fully revised data, they do not perform better than the random walk model.

Molodtsova and Papell (2008), exploiting recent econometric work by Clark and West (2006), test the out-of-sample predictability of nominal exchange rate changes using Taylor rule fundamentals for 12 countries from 1973 to 2006. While real-time data is not available during the post-Bretton Woods period for most of the countries, they construct output gaps as deviations from "quasi-revised" trends in potential output, where the trends, while incorporating data revisions, are updated each period so as not to incorporate *ex post* data. Although they find strong evidence of short-run predictability with quasi-revised data for most of the considered currencies using Taylor rule fundamentals, they do not produce forecasts with real-time data.[2]

In Molodtsova, Nikolsko-Rzhevskyy, and Papell (2008), we integrate research on monetary policy evaluation and out-of-sample exchange rate predictability with real-time data. We estimate Taylor rule interest rate reaction functions with real-time data for the United States and Germany from 1979, the beginning of the European Monetary System (EMS), through 1998, the advent of the Euro, and use these specifications as fundamentals for evaluating out-of-sample predictability of the United States Dollar/Deutsche Mark nominal exchange rate. We find that evidence of predictability increases with the use of real-time, rather than revised, data and with models that allow differential inflation and output coefficients in the Federal Reserve and Bundesbank reaction functions and include the exchange rate in the Bundesbank reaction function.

This paper uses real-time data to evaluate out-of-sample predictability of the United States Dollar/Euro exchange rate from the inception of the Euro in 1999 to the end of 2007. We first ask whether Taylor rules appear to be a reasonable approximation of interest rate setting for the United States and the Euro area during this period. Since estimation of Taylor rules with (at most) eight years of data did not seem compelling, we start with visual evidence from a standard Taylor rule specification, similar to that presented

[2] Engel, Mark and West (2007) use a more constrained version of the Molodtsova and Papell (2008) specification with fully revised data. They find less evidence of short-horizon predictability, but more evidence of long-horizon predictability, than Molodtsova and Papell.

by Taylor (1993). We find that simple Taylor rules generally track the direction of interest rate movements for both the Federal Reserve System (Fed) and the European Central Bank (ECB), although the fit is not nearly as close as in Taylor (1993). In particular, the shortfall of the Federal Funds Rate below the Taylor rule rate for the United States for 2002 to 2006, emphasized by Taylor(2007) as a cause of the housing price bubble, is also evident with real-time data.

Having established that Taylor rules provide, at the least, some information that is useful for understanding Fed and ECB monetary policy, we proceed to see if they are useful for out-of-sample exchange rate predictability. At the onset, we need to make clear the distinction between forecasting and predictability. If we were evaluating forecasts from two non-nested models, we could compare the mean squared prediction errors (MSPE) from the two models, scaled to produce the DMW statistic, and determine whether one model forecasts better than the other. In our case, however, the null hypothesis of a random walk and all alternative models are nested and we use the Clark and West (2006) adjustment of the DMW statistic to achieve correct size. Predictability, whether the vector of coefficients on the Taylor rule fundamentals is jointly significantly different from zero in a regression with the change in the exchange rate on the left-hand-side, is therefore not equivalent to forecasting content, whether the MSPE from the alternative model is significantly smaller than the MSPE from the null model. Put differently, we are using out-of-sample methods to evaluate the Taylor rule exchange rate model, not investigating whether the model would potentially be useful to currency traders.[3]

We examine out-of-sample exchange rate predictability with Taylor rule fundamentals. The starting point for our analysis is the same as for the Taylor rule model of exchange rate determination, the Taylor rule for the Euro Area is subtracted from the Taylor rule for the United States. There are a number of different specifications that we consider. While each specification has the interest rate differential on the left-hand-side, there are a number of possibilities for the right-hand-side variables.

1. Taylor posited that the Fed sets the nominal interest rate based on the current inflation rate, the inflation gap - the difference between inflation and the target inflation rate, the output gap - the difference between GDP and potential GDP, and the equilibrium real interest rate. Assuming that the ECB follows a similar rule, we construct a *symmetric* model with inflation and the output gap on the right-hand-side. Following the results in CGG for Germany, we can also posit that the ECB includes the difference between the exchange rate and the target exchange rate, defined by PPP, in its Taylor rule and construct an *asymmetric* model where the real exchange rate is also included.

2. It has become common practice, following CGG, to posit that the interest rate only partially adjusts to its target within the period. In this case, we construct a model with *smoothing* so that lagged interest

[3] This distinction has been emphasized by Inoue and Kilian (2004) and Rogoff and Stavrakeva (2008).

rates appear on the right-hand-side. Alternatively, we can derive a model with *no smoothing* that does not include lagged interest rates. Models with and without smoothing can be symmetric or asymmetric.

3. If the Fed and ECB respond identically to changes in inflation and the output gap, so that the coefficients in their Taylor rules are equal, we derive a *homogeneous* model where relative (domestic minus foreign) inflation and the relative output gap are on the right-hand-side. If the response coefficients are not equal, a *heterogeneous* model is constructed where the domestic and foreign variables appear separately. The homogeneous and heterogeneous models can be either symmetric or asymmetric, with or without smoothing.[4]

The models we have specified all have the interest rate differential on the left-hand-side. If UIRP held with rational expectations, an increase in the interest rate would cause an immediate appreciation of the exchange rate followed by forecasted (and actual) depreciation in accord with Dornbusch's (1976) overshooting model. In that case, we could derive an exchange rate forecasting equation by replacing the interest rate differential with the expected rate of depreciation and use the variables from the two countries' Taylor rules to forecast exchange rate changes, so that an increase in inflation and/or the output gap would produce a forecast of exchange rate depreciation. There is overwhelming evidence, however, that UIRP does not hold in the short run. Empirical research on the effects of monetary policy shocks on exchange rates, notably Eichenbaum and Evans (1995), shows that in response to an increase in the U.S. federal funds rate, the dollar appreciates immediately and continues to appreciate for a substantial period of time. We assume that investors use this econometric evidence for forecasting, so that the resultant increase in the country's interest rate from an increase in inflation and/or the output gap produces a forecast of exchange rate appreciation.

Using real-time data with Taylor rule fundamentals, we find very strong evidence of out-of-sample predictability for the Dollar/Euro exchange rate. The strong evidence comes almost entirely from symmetric specifications which do not include the real exchange rate in the forecasting regression. The results are robust to whether the specification is homogeneous or heterogeneous and to whether the output gap is constructed by Hodrick-Prescott (HP) filtering, taken from OECD estimates, or proxied by the unemployment rate. Specifications without smoothing provide marginally more evidence of predictability than specifications with smoothing.

Does our evidence of predictability for the Dollar/Euro exchange rate come from Taylor rule fundamentals, or is it driven by either inflation or the output gap, but not both? In order to answer this question, we estimate forecasting regressions where inflation, the HP filtered output gap, the OECD measured output gap, and the unemployment rate enter separately. The results are similar to those where

[4] If, in addition to having the same inflation response and interest rate smoothing coefficients, the two central banks have identical target inflation rates and equilibrium real interest rates, there is *no constant* on the right-hand-side. Otherwise, there is a *constant*. Since the restrictions necessary to eliminate the constant seem very unlikely to be fulfilled, we only estimate models with a constant.

inflation and a measure of economic activity enter jointly, indicating that both components of Taylor rule fundamentals are important for out-of-sample predictability.

We also investigate "predictability" with revised data, recognizing that we are no longer replicating the environment experienced by market participants. In contrast to many applications of real-time data, we expect that, because the exchange rate is an asset price, predictability can decrease with revised data because information is being used that was unavailable both when the forecasts were made and when the forecasted exchange rate was realized. We find that predictability decreases when the revised OECD measured output gap, which is consistently larger than the real-time OECD measured output gap, is in the forecasting regression. In contrast, predictability does not change with the revised HP filtered output gap or the unemployment rate, neither of which are systematically different from their real-time counterparts.

It is often asked whether the experience of the Bundesbank during the EMS period provides a good predictor for the actions of the ECB. The answer from this paper is clearly no. In our earlier work on the Mark/Dollar exchange rate with real-time data, we found evidence of predictability only with heterogeneous coefficients and asymmetric specifications, with or without smoothing. For the Euro/Dollar rate, we find that the evidence of predictability is much stronger with symmetric specifications, somewhat stronger with smoothing, and doesn't depend on whether the coefficients are homogeneous or heterogeneous.

Clarida and Waldman (2008), using an event study methodology, find evidence that a surprise increase in inflation causes the exchange rate to appreciate in the very short run for inflation targeting countries. We find strong support for our variant of their proposition that "bad news about inflation is good news for the exchange rate", which we characterize as "bad news about inflation is good news for the forecasted exchange rate." Using the most successful homogeneous and symmetric specification, an increase in U.S. inflation relative to Euro Area inflation causes forecasted dollar appreciation whatever measure of real economic activity is included in the forecasting regression. We also find that "good news about output or unemployment is good news for the forecasted exchange rate." An increase in the U.S. output gap relative to the Euro Area output gap causes forecasted dollar appreciation while an increase in U.S. unemployment relative to Euro Area unemployment causes forecasted dollar depreciation.

2. Taylor Rule Fundamentals

We examine the linkage between the exchange rate and a set of fundamentals that arise when central banks set the interest rate according to the Taylor rule. Following Taylor (1993), the monetary policy rule postulated to be followed by central banks can be specified as

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

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. It is assumed that the target for the short-term nominal interest rate is achieved within the period so there is no distinction between the actual and target nominal interest rate. Alternatively, the difference between the natural rate of unemployment and the unemployment rate can replace the output gap.[5]

According to the Taylor rule, the central bank raises the target for the short-term nominal interest rate if inflation rises above its desired level and/or output is above potential output. The target level of the output deviation from its natural rate y_t is 0 because, according to the natural rate hypothesis, output cannot permanently exceed potential output. The target level of inflation is positive because it is generally believed that deflation is much worse for an economy than low inflation. Taylor assumed that the output and inflation gaps enter the central bank's reaction function with equal weights of 0.5 and that the equilibrium level of the real interest rate and the inflation target were both equal to 2 percent.

The parameters π_t^* and r^* in equation (1) can be combined into one constant term $\mu = r^* - \phi\pi_t^*$, which leads to the following equation,

(2) $$i_t^* = \mu + \lambda\pi_t + \gamma y_t$$

where $\lambda = 1 + \phi$.

While it seems reasonable to postulate a Taylor rule for the United States that includes only inflation and the output gap, it is common practice to include the real exchange rate in specifications for other countries,

(3) $$i_t^* = \mu + \lambda\pi_t + \gamma y_t + \delta q_t$$

where q_t is the real exchange rate for the Euro Area. The rationale for including the real exchange rate in the Taylor rule is that the central bank sets the target level of the exchange rate to make PPP hold and increases (decreases) the nominal interest rate if the exchange rate depreciates (appreciates) from its PPP value. Based on the evidence in CGG and Molodtsova, Nikolsko-Rzhevskyy, and Papell (2008) that the real exchange rate entered the Taylor rule for the Bundesbank during the European Monetary System period, we allow for the possibility that it should be included in the ECB's Taylor rule.

It has also become common practice to specify a variant of the Taylor rule which allows for the possibility that the interest rate adjusts gradually to achieve its target level. Following CGG, we assume that the actual observable interest rate i_t partially adjusts to the target as follows:

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

[5] Blinder and Reis (2005) use this measure.

Substituting (3) into (4) gives the following equation,

$$i_t = (1-\rho)(\mu + \lambda\pi_t + \gamma y_t + \delta q_t) + \rho i_{t-1} + v_t \tag{5}$$

where δ = 0 for the United States.

To derive the Taylor-rule-based forecasting equation, we construct the interest rate differential by subtracting the interest rate reaction function for the Euro Area from that for the U.S.:

$$i_t - \tilde{i}_t = \alpha + \alpha_{u\pi}\pi_t - \alpha_{e\pi}\tilde{\pi}_t + \alpha_{uy}y_t - \alpha_{ey}\tilde{y}_t - \alpha_q\tilde{q}_t + \rho_u i_{t-1} - \rho_e\tilde{i}_{t-1} + \eta_t \tag{6}$$

where ~ denotes Euro Area variables, subscripts u and e denote coefficients for the United States and the Euro Area, α is a constant, $\alpha_\pi = \lambda(1-\rho)$ and $\alpha_y = \gamma(1-\rho)$ for both central banks, and $\alpha_q = \delta(1-\rho)$ for the ECB.[6]

Suppose that U.S. inflation rises above target. If there is no smoothing, all interest rate adjustments are immediate. The Fed will raise the interest rate by $\lambda\Delta\pi$, where $\Delta\pi$ is the change in the inflation rate. How will the increase in the interest rate differential affect exchange rate forecasts? According to the results in Eichenbaum and Evans (1995), a positive shock to the federal funds rate leads to delayed overshooting, both immediate and sustained exchange rate appreciation, with the maximal impact occurring between 22 and 33 months after the shock, followed by depreciation. This is clearly inconsistent with UIRP with rational expectations, which constrains the maximal impact to occur immediately.[7] Faust and Rogers (2003) and Scholl and Uhlig (2008), while questioning their identification procedure, also find large UIRP deviations in response to monetary policy shocks.[8] Assuming that investors use these empirical results for forecasting, we postulate that an increase in U.S. inflation above target will cause forecasted dollar appreciation in the short run. A similar argument would imply that an increase in Euro Area inflation above its target would lead to forecasted euro appreciation.[9]

With interest rate smoothing, higher inflation not only raises the current interest rate, it causes expectations of further interest rate increases in the future. Again suppose that either U.S. or Euro Area inflation rises above target. If there is smoothing, the adjustment is gradual. The Fed or ECB will raise the

[6] As shown by Engel and West (2005), this specification would still be applicable if the U.S. had an exchange rate target in its interest rate reaction function.

[7] Gourinchas and Tornell (2004) show that an increase in the interest rate can cause sustained exchange rate appreciation if investors systematically underestimate the persistence of interest rate shocks.

[8] This is related to the extensive literature on the forward premium puzzle, where regressions of ex post changes of exchange rates on interest rate differentials typically yield a coefficient estimate that is both negative and statistically different from zero. The survey by Froot and Thaler (1990) reports an average estimate of -0.88 among 75 studies. While these results provide evidence of the failure of unconditional UIRP, the response of the exchange rate to all shocks on average, they are not as directly related to our research as the evidence on the failure of UIRP conditional on monetary policy shocks.

[9] Clarida and Waldman (2008) construct a model that combines a Taylor rule with a Phillips curve to derive conditions under which a surprise increase in U.S. inflation will appreciate the exchange rate. This study, however, relates inflation surprises to immediate exchange rate changes, not to exchange rate forecasts.

interest rate by (1-ρ) $\lambda\Delta\pi$ in the first period. In the second period, the interest rate will be $(1-\rho^2)\lambda\Delta\pi$ above its original level, followed by $(1-\rho^3)\lambda\Delta\pi$, and so on. The maximum impact on the interest rate will be approximately $\lambda\Delta\pi$, the same as with no smoothing. Interest rate smoothing does not affect the results. Under UIRP and rational expectations, an increase in the interest rate, whether current or expected in the future, will cause an immediate appreciation of the exchange rate, followed by forecasted (and actual) depreciation. In the context of delayed overshooting, the combination of current and expected future increases in the interest rate will cause forecasted short-run exchange rate appreciation.

The link between higher inflation and exchange rate appreciation potentially characterizes any country where the central bank uses the interest rate as the instrument in an inflation targeting policy rule. In the context of the Taylor rule, three additional predictions can be made. First, if the U.S. output gap increases, the Fed will raise interest rates and cause the dollar to appreciate. Similarly, an increase in the Euro Area output gap will cause the euro to appreciate. Second, if the real exchange rate for the Euro Area depreciates and it is included in the ECB's Taylor rule, the ECB will raise its interest rate, causing the Euro to appreciate and the dollar to depreciate. Third, if there is interest rate smoothing, a higher lagged interest rate will increase current and expected future interest rates. Under UIRP and rational expectations, any event that causes the Fed or ECB to raise its interest rate will produce immediate exchange rate appreciation and forecasted depreciation. Based on the evidence discussed above, however, we believe it is more reasonable to postulate that these events will produce both immediate and forecasted appreciation.

These predictions can be combined with (6) to produce an exchange rate forecasting equation.

$$\Delta s_{t+1} = \omega - \omega_{u\pi}\pi_t + \omega_{e\pi}\tilde{\pi}_t - \omega_{uy}y_t + \omega_{ey}\tilde{y}_t + \omega_q\tilde{q}_t - \omega_{ui}i_{t-1} + \omega_{ei}\tilde{i}_{t-1} + \eta_t \tag{7}$$

The variable s_t is the log of the U.S. dollar nominal exchange rate determined as the domestic price of foreign currency, so that an increase in s_t is a depreciation of the dollar. The reversal of the signs of the coefficients between (6) and (7) reflects the presumption that anything that causes the Fed and/or ECB to raise the U.S. interest rate relative to the Euro Area interest rate will cause the dollar to appreciate (a decrease in s_t). Since we do not know by how much a change in the interest rate differential (actual or forecasted) will cause the exchange rate to adjust, we do not have a link between the magnitudes of the coefficients in (6) and (7).

A number of different models can be nested in Equation (7). If the ECB doesn't target the exchange rate $\delta = \omega_q = 0$ and we call the specification symmetric. Otherwise, it is asymmetric. If the interest rate adjusts to its target level within the period $\omega_{ui} = \omega_{ei} = 0$ and the model is specified with no smoothing. Alternatively, there is smoothing. If the coefficients on inflation, the output gap, and interest rate smoothing are the same in the U.S. and the Euro Area, so that $\omega_{u\pi} = \omega_{e\pi}$, $\omega_{uy} = \omega_{ey}$, and $\omega_{ui} = \omega_{ei}$, inflation, output gap, and lagged interest rate differentials are on the right-hand-side of Equation (7) and we call the model homogeneous. Otherwise, it is heterogeneous.

3. Taylor Rules, the Fed, and the ECB

If we were writing this paper in 2018 instead of 2008, we would start by estimating Taylor rules using real-time data for the Fed and ECB to provide a guide to the factors that might affect out-of-sample exchange rate predictability. Since that option is precluded and we are skeptical that much can be learned from estimating Taylor rules with eight years of data, we start with a more descriptive method. We first describe the real-time data available for the U.S. and Euro Area since 1999, and then provide visual evidence that Taylor rules with real-time data provide a useful characterization of interest rate setting by the Fed and ECB.[10]

3.1 Real-Time and Revised Data

We use real-time quarterly data from 1999:Q4 to 2007:Q4 for the United States and the Euro Area. The real-time data for the U.S. comes from Philadelphia Fed Real-Time Dataset for Macroeconomists, described in Croushore and Stark (2001), and the real-time data for the Euro Area is from the OECD Original Release and Revisions Database.[11] Both data sets have a triangular format with the vintage date on the horizontal axis and calendar dates on the vertical. The term vintage denotes the date in which a time series of data becomes known to the public.[12] For each subsequent quarter, the new vintage incorporates revisions to the historical data, thus providing all information known at the time. The revised data is constructed from the 2007:Q4 vintage in both real-time datasets.

For each forecasting regression, we start in 1991:Q1 and use 34 quarters to estimate the historical relationship between the Taylor rule fundamentals and the change in the exchange rate, and then use the estimated coefficients to forecast the exchange rate one-quarter-ahead. We use rolling regressions to predict 32 exchange rate changes from 2000:Q1 to 2007:Q4. Since we use vintage data, the estimated coefficients are based on revised data, but the forecasts are conducted using real-time data. [13]

We use the GDP Deflator to measure inflation for the U.S. and the Harmonized Index of Consumer Prices (HICP) to measure inflation for Euro Area. Following Taylor (1993), the inflation rate is the rate of inflation over the previous four quarters. The exchange rate, defined as the quarterly-averaged US dollar price of a Euro, and the short-term nominal interest rates, defined as the interest rate in the third month of each

[10] Recent papers that compare Taylor rules for the Fed and ECB, including De Lucia and Lucas (2007) and Gerdesmeier, Mongelli, and Roffia (2007), use either Bundesbank or synthetic Euro Area data to extend the sample back to 1993, and therefore cannot use real-time data.

[11] An alternative would be to use Euro Area Business Cycle Network data, but it does not start until 2001.

[12] There is typically a one-quarter lag before data is released, so real-time variables dated time t actually represent data through period t-*1*.

[13] An alternative method of constructing real-time data is to use "diagonal" data that does not incorporate historical revisions. With that method, the estimated coefficients would also use real-time data. Since the vintages are not available before 1999 and we only have 32 forecast periods, we do not have that option for this paper.

quarter, are taken from OECD Main Economic Indicators (MEI) database. The short-term interest rate is the money market rate (EONIA) for Euro Area and the Federal Funds Rate for the U.S. Since interest data for the Euro Area does not exist prior to 1994:Q4, we use the German money market rate from the IMF International Financial Statistics Database (line 60B) for the earlier period. The real Euro/USD exchange rate is calculated as the deviation of the nominal exchange rate from the target defined by Purchasing Power Parity, where the two countries' price levels are measured by the CPI for the U.S. and the HICP for the Euro Area.

We use two different measures of the output gap. First, we construct quarterly measures of the output gap from internal OECD estimates. This data comes from the semi-annual issues of OECD Economic Outlook. Each issue contains past estimates as well as future forecast of annual values of the output gap for OECD countries including the European Union. Since both estimates and forecasts are annual, we used quadratic interpolation to obtain quarterly estimates.[14] The second measure of the output gap uses HP detrended real industrial production.[15] Industrial production data starts in 1990:Q1. While applying the HP filter, we take account of the end-of-sample problem by forecasting and backcasting the industrial production series by 12 quarters in both directions assuming that growth rates follow an AR(4) process. A similar methodology is used in Clausen and Meier (2005).

The forward-looking specifications use the Philadelphia Fed Survey of Professional Forecasters (SPF) forecast data, which originally consists of annualized quarter-over-quarter GDP deflator inflation forecasts at different horizons. We convert it into year-over-year rates by taking the average of 4 consecutive inflation forecasts. For the U.S., SPF data is available for the entire sample. For the Euro Area, the only comparable SPF data which is available is the 1-year-ahead HICP inflation forecast. The first round of the survey was conducted in 1999:Q1. This means that we do not have the same forecast for 1991:Q1, which is the starting point for our "vintage" regressions. To deal with this issue, we note that the first "vintage" regression which the public could have run using OECD real-time data was in 1999:Q4 when the first OECD vintage was published. At that time, inflation data for 1990:Q1-1999:Q3 was available. To construct the t+4 inflation forecast for any vintage, we use the realized t+4 values of inflation (which is sometimes interpreted as the "rational" t+4 forecast of inflation) before 1998:Q4 and real-time Euro Area SPF forecasts from 1999:Q1 to 2007:Q4.

The real-time and revised data are depicted in Figure 1. In line with all research in this area since Orphanides (2001), the differences are much larger for output gaps than for inflation, reflecting the changes in potential output, as well as the data revisions themselves, for the former but not the latter. Revisions in

[14]Since the data is updated semi-annually, we assume that in the quarter following the period in which the estimates are released, the public uses the estimates and forecasts from the previous quarter. They get updated only after the next release of the Economic Outlook. See Nikolsko-Rzhevskyy (2008) for details.

[15] We use industrial production instead of GDP because the latter does not start until 1995 for the Euro Area in the OECD database.

unemployment are much smaller than revisions in the output gaps for both the U.S. and the Euro Area. For the U.S., the revisions in the HP filtered output gap are larger than the revisions in the OECD estimated output gap, while the opposite is true for the Euro Area. The largest revisions are for the OECD real-time estimates of the output gap for the Euro Area, which are substantially below the revised estimates from 1999:Q4 to 2004:Q2.

These points are illustrated in Table 1 that provides summary statistics of revised and real-time data. The average U.S. real-time inflation and unemployment rate are virtually the same as the revised inflation and unemployment rate and the average Euro Area real-time inflation and unemployment rate differ from their revised counterparts insignificantly. The largest differences are found between the average U.S. real-time and revised HP filtered output gap and Euro Area OECD output gap. These differences are very close in size and equal to 1.14 percentage points for the U.S. and 1.13 percentage points for Euro Area. The average U.S. real-time and revised OECD output gap and Euro Area real-time and revised HP filtered output gap differ by 0.05 and 0.11 percentage points, respectively. These differences suggest that policy recommendations based on HP filtered output gap for the U.S. and OECD estimates of the output gap for the Euro Area may be substantially different with revised and real-time data.

Table 2 shows the descriptive statistics on data revisions in our sample. A positive and significant value for the mean of the revision indicates that the variable was on average revised upwards, so that the existence of measurement errors or the availability of new information (or both) made the statistical agency realize that the inflation rate and/or the output gap was higher than perceived in real-time. We can see that the mean revision for inflation and unemployment is essentially zero for the U.S., and insignificant for Euro Area. Both HP filtered output gap for the U.S. and OECD estimates of the output gap for the Euro Area are on average revised upwards.

To explore the nature of data revisions in our sample, we examine the correlations between the data revisions, defined as $X_{revised}$-$X_{real\text{-}time}$, and the real-time and revised series. According to Mankiw and Shapiro (1986), if data revisions represent pure noise, they should be uncorrelated with the revised data but correlated with the real-time series. The opposite should be true if data revisions represent pure news. The correlations in Table 2 indicate that revisions in the Euro Area HP filtered output gap represent pure news and revisions in Euro Area OECD output gap are dominated by news. The revisions in Euro Area inflation and unemployment represent mostly noise. The properties of news are more pronounced in the U.S. revisions of inflation and the HP filtered output gap, while revisions of the U.S. OECD output gap and unemployment are dominated by noise.

3.2 Taylor Rules for the Fed and ECB

We provide visual evidence of how closely interest rate setting by the Fed and the ECB can be characterized by a Taylor rule with real-time data. In panel A of Figure 2, we depict the actual U.S. and Euro Area interest rate and the counterfactual interest rate implied by a Taylor rule with a coefficient of 1.5 on inflation, 0.5 on the output gap, an inflation target of 2 percent, an equilibrium real interest rate of 2 percent, and no smoothing. Except for using real-time rather than revised data and a different time period, this is exactly the exercise conducted in Taylor (1993). We use GDP real-time inflation for the US, HICP real-time inflation for the Euro Area, and OECD estimates of the output gap.[16]

The results for the U.S. show that, while the Federal Funds rate and interest rate implied by the Taylor rule are clearly positively correlated, the Federal Funds rate is consistently below the rate implied by the Taylor rule from 2002:Q4 to 2007:Q1, nearly exactly replicating the results reported by Taylor(2007) with revised data.[17] Taylor(2007) argues that the gap between the actual Federal Funds rate and the rate implied by the Taylor rule was an important contributing factor to the housing price bubble in the U.S. Our results show that, in the context of this argument, the discrepancy is not an artifact of using revised data that were not available to the Fed at the time that interest-rate-setting decisions were made, but also appears in real-time data. For the Euro Area, while the overall fit is closer, the actual Money Market Rate is below the rate implied by the Taylor rule from 2003:Q1 to 2007:Q1. While this is similar to the pattern found for the U.S., the magnitude of the gap is much smaller for the Euro Area than for the U.S.

It is often argued that monetary policy evaluation should be conducted with forward-looking data. In panel B of Figure 2, we depict forward-looking specifications, for which we use the t+4 SPF inflation forecasts for both the Euro Area and the U.S. Everything else, including the coefficients on inflation and the output gap, the inflation target of 2 percent, and the equilibrium real interest rate of 2 percent, is the same as with contemporaneous inflation. For the U.S., the pattern is similar to that found with contemporaneous inflation except that it starts in 2002:Q3 and ends in 2005:Q4. In addition, the gap between the actual Federal Funds rate and the rate implied by the Taylor rule is smaller with forecasted inflation. For the Euro Area, the actual Money Market rate with forecasted inflation is very close to the rate implied by the Taylor rule for almost the entire period, with the actual rate higher in 2000-2001 and the implied rate higher in 2004-2006.

With forecasted inflation, we can construct *ex ante* real interest rates as the nominal interest rate minus the expected rate of inflation, and calculate the equilibrium real interest rate, 1.45 percent for the U.S. and 1.33 percent for the Euro Area, as the average real interest rate over the period.[18] The results with a forward-looking specification and calculated equilibrium real interest rate are shown in panel C. According to Equation (1), the equilibrium real interest rate has a point-for-point affect on the nominal interest rate, so this lowers the interest rate implied by the Taylor rule by 0.55 percent for the U.S. and 0.67 percent for the Euro Area. For the U.S., the gap between the actual Federal Funds rate and the rate implied by the Taylor rule starts in 2002:Q3 and ends in 2005:Q4 and is smaller than that found with an equilibrium real interest rate of

[16] Figures for HP filtered data (not reported) are similar.
[17] In Taylor(2007), the actual and implied paths diverge in 2002:Q2 and merge again in 2006:Q3.
[18] Because the equilibrium real interest rate is calculated by averaging over the period, this is not literally a real-time exercise even though it uses real-time inflation and output gap data.

2 percent. For the Euro Area, the actual Money Market rate with forecasted inflation is above the rate implied by the Taylor rule for most of the period, and they are very close from 2003:Q2 to 2006:Q3.

Using real-time data visual methods that make no attempt to produce a good fit between the actual and implied interest rates, we have shown that the Taylor rule provides a good approximation of interest rate setting by both the Fed and the ECB since 1999. For the U.S., the major deviation occurred between 2003 and 2006 and, as described by Taylor(2007), was produced because the actual Federal Funds rate was consistently below the rate implied by the Taylor rule. For the ECB, the differences between the actual and implied interest rates are smaller, and the actual Money Market rate was neither consistently above nor below the rate implied by the Taylor rule.

4. Forecast Comparison Based on MSPE

We have provided some informal evidence that, using real-time data, interest rate setting by the Fed and the ECB is broadly consistent with Taylor rule. We now turn to the central question of our paper, whether Taylor rule fundamentals can provide evidence of out-of-sample predictability for the United States Dollar/Euro exchange rate. Before addressing this issue, we need to summarize some econometric results.

Each model's out-of-sample predictability is compared to that of the martingale difference process using an adjusted test statistic, which is constructed as described in Clark and West (2006). We are interested in comparing the mean square prediction errors from the two nested models. The benchmark model is a zero mean martingale difference process, while the alternative is a linear model.

Model 1: $y_t = \varepsilon_t$

Model 2: $y_t = X_t^{'}\beta + \varepsilon_t$, where $E_{t+1}(\varepsilon_t) = 0$

Suppose we have a sample of T+1 observations. The last P observations are used for predictions. The first prediction is made for the observation *R*+1, the next for *R*+2, …, the final for *T*+1. We have *T*+1=*R*+*P*, where *R*=34, and *P*=32 quarters. To generate prediction for period *t*=*R*, *R*+1, …, *T*, we use the information available prior to *t*. Let $\hat{\beta}_t$ is a regression estimate of β_t that is obtained using the data prior to t. The one-step ahead prediction for model 1 is 0, and $X_{t+1}\hat{\beta}_t$ for model 2. The sample forecast errors from the models 1 and 2 are $\hat{e}_{1,t+1} = y_{t+1}$ and $\hat{e}_{2,t+1} = y_{t+1} - X_{t+1}\hat{\beta}_t$, respectively. The corresponding MSPE's for the two models are $\hat{\sigma}_1^2 = P^{-1}\sum_{t=T-P+1}^{T} y_{t+1}^2$ and $\hat{\sigma}_2^2 = P^{-1}\sum_{t=T-P+1}^{T}(y_{t+1} - X'_{t+1}\hat{\beta}_t)^2$.

We are interested in testing the null hypothesis of no predictability against the alternative that exchange rates are linearly predictable.[19] Thus,

$$H_0 : \sigma_1^2 - \sigma_2^2 = 0$$

$$H_1 : \sigma_1^2 - \sigma_2^2 > 0$$

Under the null, the population MSPE's are equal. We need to use the sample estimates of the population MSPE's to draw the inference. The procedure introduced by Diebold and Mariano (1995) and West (1996) uses sample MSPE's to construct a t-type statistics which is assumed to be asymptotically normal. To construct the DMW statistic, let

$$\hat{f}_t = \hat{e}_{1,t}^2 - \hat{e}_{2,t}^2 \qquad \text{and} \qquad \bar{f} = P^{-1} \sum_{t=T-P+1}^{T} \hat{f}_{t+1} = \hat{\sigma}_1^2 - \hat{\sigma}_2^2$$

Then, the DMW test statistic is computed as follows,

$$DMW = \frac{\bar{f}}{\sqrt{P^{-1}\hat{V}}}, \qquad \text{where} \qquad \hat{V} = P^{-1} \sum_{t=T-P+1}^{T} (\hat{f}_{t+1} - \bar{f})^2 \tag{8}$$

Clark and West (2006) demonstrate analytically that the asymptotic distributions of sample and population difference between the two MSPE's are not identical, namely the sample difference between the two MSPE's is biased downward from zero. This means that using the test statistic (8) with standard normal critical values is not advisable.

It is straightforward to show that the sample difference between the two MSPE's is uncentered under the null.

$$\hat{\sigma}_1^2 - \hat{\sigma}_2^2 = P^{-1} \sum_{t=T-P+1}^{T} \hat{f}_{t+1} = P^{-1} \sum_{t=T-P+1}^{T} y_{t+1}^2 - P^{-1} \sum_{t=T-P+1}^{T} (y_{t+1} - X_{t+1}'\hat{\beta}_t)^2 = 2P^{-1} \sum_{t=T-P+1}^{T} y_{t+1} X_{t+1}'\hat{\beta}_t - P^{-1} \sum_{t=T-P+1}^{T} (X_{t+1}'\hat{\beta}_t)^2 \tag{9}$$

Under the null, the first term in (9) is zero, while the second one is greater than zero by construction. Therefore, under the null we expect the MSPE of the naïve no-change model to be smaller than that of a linear model. The intuition behind this result is the following. If the null is true, estimating the alternative model introduces noise into the forecasting process because it is trying to estimate parameters which are zero in population. Use of the noisy estimate will lead to a higher estimated MSPE and, as a result, the sample MSPE of the alternative model will be higher by the amount of estimation noise.

To properly adjust for this shift, we construct the corrected test statistic as described in Clark and West (2006) by adjusting the sample MSPE from the alternative model by the amount of the bias in the second term of equation (9). This adjusted CW test statistic is asymptotically standard normal. When the null

[19] We use the term "predictability" as a shorthand for "out-of-sample predictability" in the sense used by Clark and West (2006, 2007), rejecting the null of a zero slope in the predictive regression in favor of the alternative of a nonzero slope.

is a martingale difference series Clark and West (2006, 2007) recommend adjusting the difference between MSPE's as described above and using standard normal critical values for inference.[20]

It is important to understand the distinction between predictability and forecasting content. The CW methodology tests whether the regression coefficient β is zero rather than whether the model-based forecast is more accurate than the random walk forecast. Since the CW statistic is constructed by adjusting the sample MSPE from the alternative model by the amount of bias under the null, it is entirely possible for the null hypothesis that $\beta = 0$ to be rejected even when the sample MSPE from the random walk forecast is smaller than the sample MSPE from the model-based forecast.

5. Empirical Results

5.1 Taylor Rule Fundamentals

We now turn to our empirical results. Tables 3-7 present results for one-quarter-ahead forecast comparisons using CW statistics. Table 3 presents the central results of the paper. With a symmetric specification that does not include the real exchange rate in the forecasting regression, no smoothing, and heterogeneous coefficients, the random walk (no predictability) null hypothesis is rejected at the 1 percent level in favor of the alternative hypothesis of out-of-sample predictability for the Euro/Dollar exchange rate with Taylor rule fundamentals when both inflation and either the HP filtered output gap, the OECD estimated output gap, or the unemployment rate is included in the forecasting regression. With a symmetric specification, no smoothing, and homogeneous coefficients, the rejections are nearly as strong, 1 percent for inflation and either the HP filtered output gap or the unemployment rate and 10 percent for inflation and the OECD output gap estimate.

The results for symmetric specifications with smoothing are also strong. With heterogeneous coefficients, the null is rejected at the 1 percent level for inflation and the HP filtered output gap and at the 5 percent level for inflation and either the OECD estimated output gap or the unemployment rate while, with homogeneous coefficients, the null is rejected at the 1 percent level for inflation and either the HP filtered output gap or the unemployment rate and at the 10 percent level for inflation and the OECD output gap estimate. The results for the asymmetric specifications, which include the real exchange rate in the forecasting regression, are much weaker. While, with no smoothing and homogeneous coefficients, the null is rejected at the 5 percent level for inflation and either the HP filtered output gap or the unemployment rate and at the 10 percent for inflation and the OECD output gap estimate, it can only be rejected, at the 10 percent level, for

[20] Because the null hypothesis for the CW statistic is a zero mean martingale difference process, we can only test the null that the exchange rate is a random walk, not a random walk with drift. Clark and West (2006, 2007) argue that standard normal critical values are approximately correct and advocate using them instead of bootstrapped critical values. Clark and McCracken (2008) consider the impact of data revisions on tests of equal predictive ability. Because the nominal exchange rate is unrevised and a random walk under the null, even predictable real-time data revisions do not have an impact on the asymptotic distributions and the Clark and West results can be used.

the OECD output gap estimate with heterogeneous coefficients. With smoothing, the null cannot be rejected at the 10 percent level for any of the specifications.

We have presented evidence that, using symmetric specifications that do not include the real exchange rate in the forecasting regression, the random walk (no predictability) null hypothesis can be consistently rejected in favor of the alternative hypothesis of out-of-sample predictability for the Euro/Dollar exchange rate with Taylor rule fundamentals. Since the specifications include inflation and either the HP filtered output gap, the OECD estimated output gap, or the unemployment rate in the forecasting regression, it is not clear, however, whether the source of the rejections comes from inflation, a measure of real economic activity, or both.

This question is addressed in Table 4 by reporting CW statistics when either inflation or a measure of real economic activity, instead of both, is included in the forecasting regressions. For the symmetric specifications without smoothing, the random walk (no predictability) null can be rejected in favor of the alternative at the 1 percent level with the HP filtered output gap, the OECD output gap estimate, and the unemployment rate and at the 5 percent for inflation with both homogeneous and heterogeneous coefficients. Because the null can be rejected when either inflation or any of the real economic activity measures are included in the forecasting regression, this constitutes evidence of out-of-sample exchange rate predictability from a specification with Taylor rule fundamentals rather than a specification that is solely focused on either inflation or real activity.[21] As with the specifications that include both variables, the evidence of predictability weakens with a symmetric specification with smoothing, weakens further with an asymmetric specification without smoothing, and disappears with an asymmetric specification with smoothing.

The next topic that we consider is "predictability" with revised data. While we subscribe to the view that, because revised data was not available to market participants at the time forecasts were made, only real-time data should be used to evaluate predictability, the use of revised data is so ubiquitous in the out-of-sample literature that we choose to use it. The results with revised data are reported in Table 5. For the symmetric specifications with either homogeneous or heterogeneous coefficients, the evidence of out-of-sample exchange rate predictability is equal to that with real-time data when inflation and either the HP filtered output gap or the unemployment rate are in the forecasting regression. The evidence of predictability, however, weakens when inflation and the OECD estimated output gap are included. This is consistent with the visual evidence in Figure 1 that the differences between the revised and real-time data are larger for the OECD estimated output gap than for the either the HP filtered output gap or the unemployment rate.

[21] If the random walk null was not rejected with either inflation or the real economic activity measures, that would also have constituted evidence of predictability with Taylor rule fundamentals. If, however, the null was rejected for either inflation or the real activity measures, but not both, that would not have been evidence of predictability with Taylor rule fundamentals.

It is often argued that forward-looking monetary policy rules provide a superior description of central banks' behavior than rules based on the most recent estimates of inflation. Following Orphanides (2001, 2003), most of this literature uses Greenbook forecasts for the U.S. Since Greenbook forecasts are not publicly available past 2002 and there is no equivalent for the ECB, we use SPF forecasts for both. The results are depicted in Table 6 with the current inflation rate replaced by forecasted inflation four quarters ahead.[22] We find no evidence that out-of-sample exchange rate predictability is improved by using forecasted rather than actual inflation. For the two most successful specifications, the symmetric model with and without smoothing, there is very little difference between using current and forecasted inflation. This is in accord with Taylor's (1999) view that, because they incorporate the same information, inflation forecast rules are no more forward-looking than rules based on lagged data. For the two less successful asymmetric specifications, the evidence of predictability decreases without smoothing and remains nonexistent with smoothing.

A second example of forward-looking Taylor rules, also considered by Orphanides (2003), adds the forecasted rate of growth of the OECD estimated output gap (which is equivalent to the forecasted rate of output growth minus the forecasted rate of potential output growth) to the specifications that include inflation forecasts and a measure of real economic activity.[23] The results of adding forecasts of output gap growth to our forecasting regression are depicted in Table 7. Although this specification has intuitive appeal and has worked well in estimation of Taylor rules for the U.S., it worsens out-of-sample predictability for the Dollar/Euro exchange rate. The evidence of predictability decreases for the symmetric specifications and remains low-to-nonexistent for the asymmetric specifications.

5.2 Testing for Superior Predictive Ability

Since we are testing simultaneously hypotheses that involve 24 different alternative models, conventional p-values can be misleading. As a result of extensive specification search, we may mistake significant results generated by chance for genuine evidence of predictive ability. To address the issue of multiple hypothesis testing, we perform the test of superior predictive ability (SPA) proposed by Hansen (2005). The SPA test is designed to compare the out-of-sample performance of a benchmark model to that of a set of alternatives. This approach is a modification of the reality check for data snooping developed by White (2000). The advantages of the SPA test are that it is more powerful and less sensitive to the introduction of poor and irrelevant alternatives.[24]

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[22] Given the one-quarter lag in data releases, we use forecasts of inflation made in period t with data through period $t-1$ for period $t+3$.

[23] Orphanides (2003) shows how this rule relates to monetary growth targeting.

[24] Hansen (2005) provides details on the construction of the test statistic and confirms the advantages of the test by Monte Carlo simulations. We use the publicly available software package MULCOM to construct the SPA-consistent p-values for each country. The code, detailed documentation, and examples can be found at http://www.hha.dk/~alunde/mulcom/mulcom.htm

We are interested in comparing the out-of-sample performance of linear exchange rate models to a naïve random walk benchmark. The SPA test can be used for comparing the out-of-sample performance of two or more models. It tests the composite null hypothesis that the benchmark model is not inferior to any of the alternatives against the alternative that at least one of the linear economic models has superior predictive ability. In the context of using the CW statistic to evaluate out-of-sample predictability, the null hypothesis is that the random walk has an MSE which is smaller than or equal to the adjusted MSE's of the linear models, as described by the last term in Equation (9). Therefore, rejecting the null indicates that at least one linear model is strictly superior to the random walk. SPA p-values take into account the search over models that preceded the selection of the model being compared to the benchmark. A low p-value suggests that the benchmark model is inferior to at least one of the competing models. A high p-value indicates that the data analyzed do not provide strong evidence that the benchmark is outperformed.

The SPA test is designed to guard against "evidence" of predictability obtained by estimating a large number of models and focusing on the one with the most significant results. With Taylor rule fundamentals, the most arbitrary choice is the measure of real economic activity, and we need to evaluate how estimating models with the HP filtered output gap, OECD estimates of the output gap, and the unemployment rate for each specification affects our evidence of predictability. The Taylor rule specifications themselves, in contrast, are not arbitrary. The choice among homogeneous (heterogeneous), symmetric (asymmetric), and smoothing (no smoothing) specifications are guided by economic theory and previous empirical research.

Table 8 reports SPA p-values for nine sets of forecasts based on symmetric and asymmetric Taylor rule specifications that are compared to a random walk forecast. The first four rows of Table 8 have three measures of economic activities as alternatives. The next four rows report SPA p-values with a larger set of alternatives for the symmetric and asymmetric Taylor rule specifications. These statistics test the random walk benchmark against six alternatives. For example, "homogenous" would denote smoothing and no smoothing for the three economic activity measures. The ninth raw, denoted "all", tests the random walk benchmark against 12 alternatives: homogenous with smoothing, homogenous with no smoothing, heterogeneous with smoothing, and heterogeneous with no smoothing for the three measures of economic activity.

The SPA p-values strongly confirm the results in Table 3. Every symmetric specification is significant at the 5 percent level and no asymmetric specification is significant at the same level.[25] Within the class of symmetric specifications, the p-values are lower for the homogeneous and no smoothing specifications than for the heterogeneous and smoothing specifications and, not surprisingly, are lowest for the homogeneous specifications without smoothing.

[25] For one of the nine specifications, homogeneous without smoothing, the null can be rejected at the 10 percent level.

5.3 Is Bad News About Inflation Good News for the Forecasted Exchange Rate?

The final topic that we consider is to explore what we are forecasting when we find evidence of out-of-sample exchange rate predictability. In Figure 3, we depict the dynamics of the coefficients on inflation and real economic activity differentials for the symmetric model with homogeneous coefficients and no smoothing which, as described in Table 8, has the lowest p-values among all specifications. As reported in Table 3, it produces significant evidence of predictability when inflation and either the HP filtered output gap or the unemployment rate are included in the forecasting regression at the 1 percent level and when inflation and the OECD estimated output gap are included at the 5 percent level.

The coefficients on the inflation differentials, reported in Figure 3 along with 90% confidence interval bands, are virtually always negative and consistently significantly different from zero for all three measures of real economic activity. Since the inflation differential equals U.S. inflation minus Euro Area inflation and the exchange rate is dollars per euro, a negative coefficient means that when U.S. inflation rises relative to Euro Area inflation, out-of-sample exchange rate predictability is achieved by forecasting dollar appreciation. This is consistent with the argument of Clarida and Waldman (2008) that "bad news about inflation is good news for the exchange rate" for inflation targeting countries. It is not consistent with using long-run PPP to forecast exchange rates, in which case an increase in U.S. inflation relative to Euro Area inflation would lead to forecasted dollar depreciation rather than appreciation. While there are many differences between the two studies - they consider multiple currencies while we examine only the Dollar/Euro rate, they use an event study methodology with a very short window while we utilize a longer one-quarter-ahead horizon, they define "news" as unexpected changes in inflation while we use actual inflation differentials, and they examine the impact of inflation news on realized exchange rate changes while we examine the effect of inflation on forecasted exchange rate changes – we reinforce their findings using a very different methodology.

Figure 3 also depicts the coefficients on the three real economic activity differentials in the same forecasting regressions. The coefficients on the output gap differentials are negative starting in 2001:Q3 and the coefficients on the unemployment differentials are positive starting in 2002:Q1, and generally are significant between 2003 and 2007. Since the output gap represents the percentage by which output exceeds potential, a positive relative output gap differential between the U.S. and the Euro Area is "good news" for the U.S. and a positive unemployment differential is "bad news" for the U.S. We find that "good news about output or unemployment is good news for the forecasted exchange rate." The negative coefficients on the U.S. output gap relative to the Euro Area output gap reflect forecasted dollar appreciation while the positive coefficients on U.S. unemployment relative to Euro Area unemployment reflect forecasted dollar depreciation.

6. Conclusions

Monetary policy evaluation of the Fed and ECB is by now overwhelmingly conducted via some variant of a Taylor rule where the short-term nominal interest rate responds to inflation and a measure of real economic activity. While nobody suggests that either the Fed or the ECB follows a mechanical rule and there is much disagreement over the coefficients and variables that enter the rule that best describes their behavior, even a cursory reading of FOMC press releases and the ECB Monthly Bulletin makes it clear why Taylor rules have become so ubiquitous. This is clear from both the Fed's dual mandate and the concern by the Governing Council of the ECB with real economic activity as well as price stability.

In this paper, we analyze whether the variables that normally enter central banks' interest-rate-setting rules, which we call Taylor rule fundamentals, can provide evidence of out-of-sample predictability of the Dollar/Euro exchange rate. We use real-time data that was available to market participants at the point that their exchange rate forecasts were conducted and are careful to distinguish between predictability and forecasting. Our results should be interpreted as an out-of-sample evaluation of exchange rate models based on Taylor rules rather than as a refutation of Meese and Rogoff (1983).

The major result of the paper is that the null hypothesis of no predictability can be rejected against an alternative hypothesis of predictability with Taylor rule fundamentals for a wide variety of specifications that include inflation and a measure of real economic activity in the forecasting regression. The results are robust to whether or not the coefficients on inflation and the real economic activity measure are constrained to be the same for the U.S. and the Euro Area and to whether or not there is interest rate smoothing. Evidence of predictability, however, is only found for specifications that do not include the real interest rate in the forecasting regression. The evidence of predictability is stronger for real-time than for revised data, about the same with inflation forecasts as with inflation rates, and weakens if output gap growth is included in the forecasting regression. Bad news about inflation and good news about real economic activity both lead to out-of-sample predictability through forecasted exchange rate appreciation.

We conclude by contributing to the debate over whether the policies followed by the Bundesbank during the EMS are a good predictor of the policies followed by the ECB. While we do not estimate policy rules and cannot answer the question directly, we can ask whether the Taylor rule specifications using real-time data that were successful in providing evidence of out-of-sample predictability for the Dollar/Mark exchange rate continue to be successful for the Dollar/Euro rate. In Molodtsova, Nikolsko-Rzhevskyy, and Papell (2008), we find the strongest evidence of predictability for the Dollar/Mark rate with heterogeneous coefficients, no smoothing, and an asymmetric specification with the real exchange rate in the forecasting regression. For the Dollar/Euro rate in this paper, this specification does not provide any evidence of predictability when the results for all three measures of real economic activity are jointly evaluated. More generally, predictability for the Dollar/Mark exchange rate is only achieved with a heterogeneous and asymmetric specification while predictability for the Dollar/Euro exchange rate is stronger with a homogeneous and symmetric specification, with the latter more important than the former. These results are consistent with the view that, like the Fed but unlike the Bundesbank, the ECB does not put much weight on the exchange rate when setting interest rates.

References

Asso, Francesco, George Kahn and Robert Leeson, "The Taylor Rule and the Transformation of Monetary Policy", Federal Reserve Bank of Kansas City RWP 07-11, 2007

Blinder, Alan S. and Ricardo Reis, "Understanding the Greenspan Standard", in *The Greenspan Era: Lessons for the Future*, Federal Reserve Bank of Kansas City, 2005, pp.11-96

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

Clarida, Richard, "Reflections on Monetary Policy Choices in the Open Economy: Implications from an Optimizing Model", unpublished, 2007

Clarida, Richard, Jordi Gali, and Mark Gertler,. "Monetary Rules in Practice: Some International Evidence" *European Economic Review*, 1998, 42, pp.1033-1067

__________, "A Simple Framework for International Monetary Policy Analysis" *Journal of Monetary Economics*, 2002, 49, pp.879-904

Clarida, Richard and Daniel Waldman, "Is Bad News About Inflation Good News for the Exchange Rate?", forthcoming, in John Y. Campbell (ed.), *Asset Prices and Monetary Policy*, University of Chicago Press, 2008

Clark, Todd E. and Michael W. McCracken, "Tests of Equal Forecast Accuracy and Encompassing for Nested Models" *Journal of Econometrics*, 2001, 105, pp.671-110

__________, "Tests of Equal Predictive Ability with Real-Time Data", Federal Reserve Bank of St. Louis Working Paper 2008-029A, 2008

Clark, Todd and Kenneth West, "Using Out-of-Sample Mean Squared Prediction Errors to Test the Martingale Difference Hypothesis" *Journal of Econometrics*, 2006, 135, pp.155-186

__________, "Approximately Normal Tests for Equal Predictive Accuracy in Nested Models" *Journal of Econometrics,* 2007, 138, pp.291-311

Clausen, Jens R. and Carsten-Patrick Meier, "Did the Bundesbank Follow a Taylor Rule? An Analysis Based on Real-Time Data" *Swiss Journal of Economics and Statistics*, 2005, 127, pp.213-246

Croushore, Dean and Tom Stark, "A Real-Time Data Set for Macroeconomists", *Journal of Econometrics*, 2001, 105, pp.111-130

De Lucia, Clemente and Jean-Marc Lucas, "How Different are the Fed and ECB?" *Conjoncture*, 2007, April-May, 16-30.

Diebold, Francis and Robert Mariano, "Comparing Predictive Accuracy" *Journal of Business and Economic Statistics*, 1995, 13, pp.253-263

Dornbusch, Rudiger, "Expectations and Exchange Rate Dynamics" *Journal of Political Economy*, 1976, 84, pp.1161-1176

Eichenbaum, Martin and Charles Evans, "Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates" *Quarterly Journal of Economics*, November 1995, CX, pp.975-1009.

Engel, Charles and Kenneth D. West, "Exchange Rate and Fundamentals" *Journal of Political Economy*, 2005, 113, pp.485-517

__________, "Taylor Rules and the Deutschmark-Dollar Real Exchange Rates" *Journal of Money, Credit and Banking*, 2006, 38, pp.1175-1194

Engel, Charles, Nelson C. Mark, and Kenneth D. West, "Exchange Rate Models Are Not as Bad as You Think", *NBER Macroeconomics Annual 2007,* University of Chicago Press, 2007, pp.381-441

Faust, Jon, John H. Rogers, and Jonathan H. Wright, "Exchange Rate Forecasting: the Errors We've Really Made" *Journal of International Economics*, 2003, 60, pp.35-59

Faust, Jon and John H. Rogers, "Monetary Policy's Role in Exchange Rate Behavior," *Journal of Monetary Economics*, 2003, 50, pp. 1403-1424

Froot, Kenneth and Richard Thaler, "Anomalies: Foreign Exchange" *Journal of Economic Perspectives*, 1990, 4, pp.179-192.

Gourinchas, Pierre-Olivier and Aaron Tornell, "Exchange Rate Puzzles and Distorted Beliefs" *Journal of International Economics*, December 2004, 64, pp.303-333.

Gerberding, Christina, Andreas Worms, and Franz Seitz, "How the Bundesbank Really Conducted Monetary Policy: An Analysis Based on Real-Time Data." *The North American Journal of Economics and Finance*, 2005, 16, pp.277-292

Gerdesmeier, Dieter and Barbara Roffia, "Taylor Rules for the Euro Area: the Issue of Real-Time Data", Discussion Paper Series 1: Economic Studies, 37, Deutsche Bundesbank, Research Centre, 2004

Gerdesmeier, Dieter, Francesco Paolo Mongelli and Barbara Roffia, "The Eurosystem, the US Federal Reserve and the Bank of Japan: Similarities and Differences" *Journal of Money, Credit, and Banking*, 2007, 39, pp.1785-1819

Gorter, Janko, Jan Jacobs, and Jakob de Haan, "Taylor Rules for the ECB Using Consensus Data" *DNB Working Paper* No.160, De Nederlandsche Bank, Amsterdam, 2007

Hansen, Peter, "A Test for Superior Predictive Ability" *Journal of Business and Economic Statistics*, 2005, 23, pp.365-380

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

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

__________, "Changing Monetary Policy Rules, Learning and Real Exchange Rate Dynamics" unpublished, University of Notre Dame, 2007

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

Molodtsova, Tanya and David H. Papell, "Exchange Rate Predictability with Taylor Rule Fundamentals" manuscript, University of Houston, 2008

Molodtsova, Tanya, Alex Nikolsko-Rzhevskyy and David H. Papell, "Taylor Rules with Real-Time Data: A tale of Two Countries and One Exchange Rate" forthcoming, *Journal of Monetary Economics*, 2008

Nelson, Edward, "UK Monetary Policy 1972-1997: A Guide Using Taylor Rules", in P. Mizen (ed.), *Central Banking, Monetary Theory and Practice: Essays in Honour of Charles Goodhart*, *Volume One*, Cheltenham, UK: Edward Elgar, 2003, pp.195-216

Nikolsko-Rzhevskyy, "Monetary Policy Evaluation in Real Time: Forward-Looking Taylor Rules without Forward-Looking Data" manuscript, University of Houston, 2008

Orphanides, Athanasios, "Monetary Policy Rules Based on Real-Time Data" *American Economic Review*, 2001, 91, pp.964–985

__________, "Historical Monetary Policy Analysis and the Taylor Rule", *Journal of Monetary Economics*, 2003, 50, pp.983-1022

__________, "Monetary Policy Rules, Macroeconomic Stability and Inflation: A View from the Trenches", *Journal of Money, Credit and Banking*, 2004, 36, pp.151-175

Rogoff, Kenneth and Vania Stavrakeva, "The Continuing Puzzle of Short Horizon Exchange Rate Forecasting," National Bureau of Economic Research Working Paper 14071, June 2008

Rudebusch, Glenn P., "Monetary Policy Inertia: A Fact or Fiction?" *International Journal of Central Banking*, 2006, 2, pp.85-135

Sauer, Stephan and Jan-Egbert Sturm, "Using Taylor Rules to Understand European Central Bank Monetary Policy" *German Economic Review*, 2007, 8, pp.375-398

Scholl, Almuth and Harald Uhlig, "New Evidence on the Puzzles: Results from Agnostic Identification on Monetary Policy and Exchange Rates," *Journal of International Economics*, 2008, 76, pp.1-14

Sturm, Jan-Egbert, and Timo Wollmershauser, "The Stress of Having a Single Monetary Policy in Europe," manuscript, CESifo, 2008

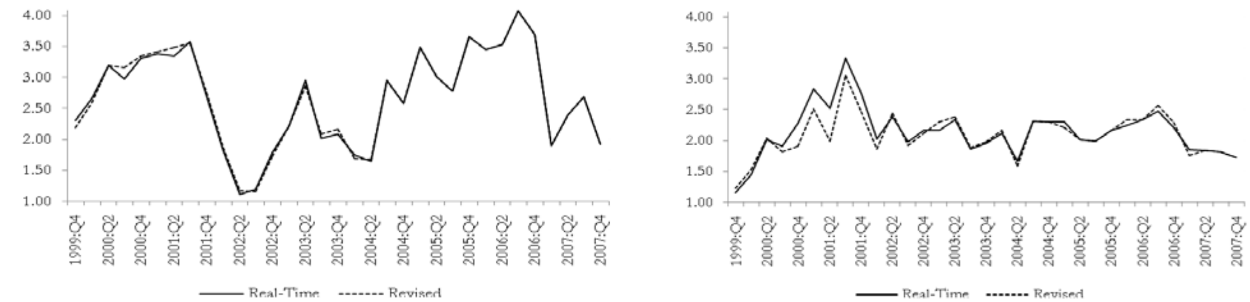
Taylor, John B., "Discretion versus Policy Rules in Practice" *Carnegie-Rochester Conference Series on Public Policy*, 1993, 39, pp.195-214

_________, 1999. The Robustness and Efficiency of Monetary Policy Rules as Guidelines for Interest Rate Setting by the European Central Bank. Journal of Monetary Economics 43, 655-679

__________, "Housing and Monetary Policy", in *Housing, Housing Finance, and Monetary Policy*, Federal Reserve Bank of Kansas City, 2007

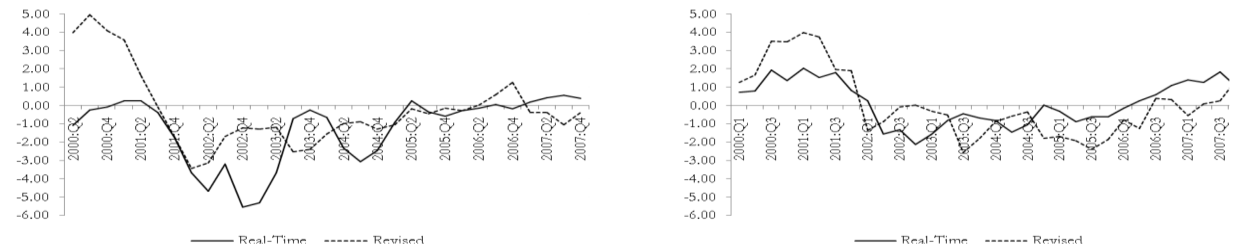
West, Kenneth D., "Asymptotic Inference about Predictive Ability" *Econometrica*, 1996, 64, pp.1067-1084

White, Halbert L., "A Reality Check for Data Snooping" *Econometrica*, 2000, 68, pp.1097-1127



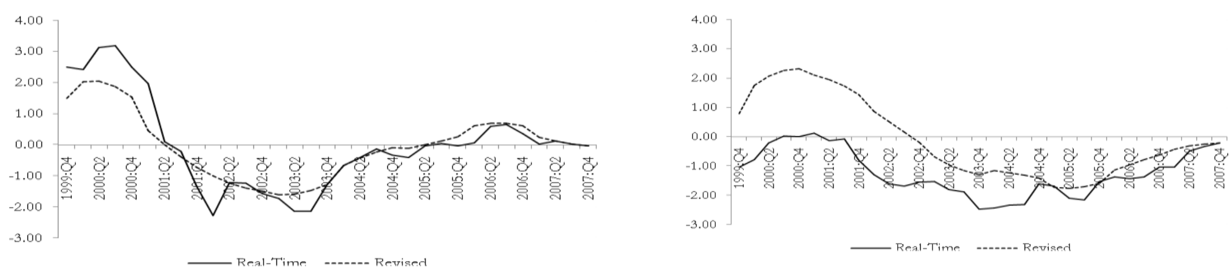
United States   Euro Area

A. Real-Time and Revised Inflation



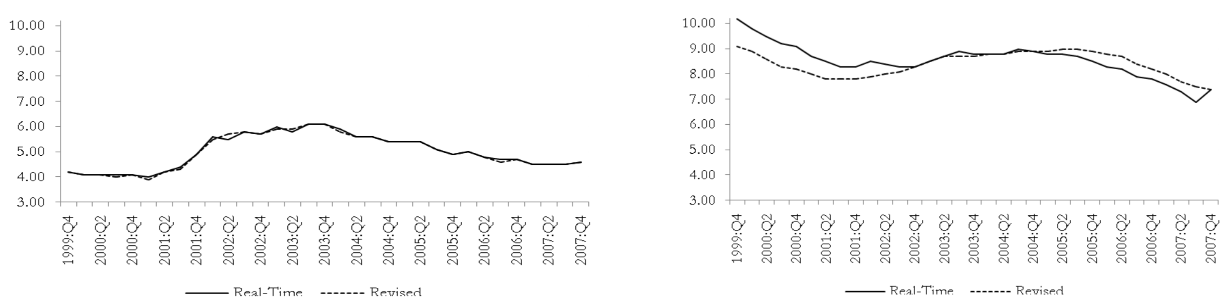
United States   Euro Area

B. Real-Time and Revised HP Filtered Output Gap



United States   Euro area

C. Real-Time and Revised OECD Estimates of Output Gap



United States   Euro Area

D. Real-Time and Revised Unemployment Rate

Figure 1. Real-Time and Revised Data for United States and Euro Area

Table 1. Summary Statistics

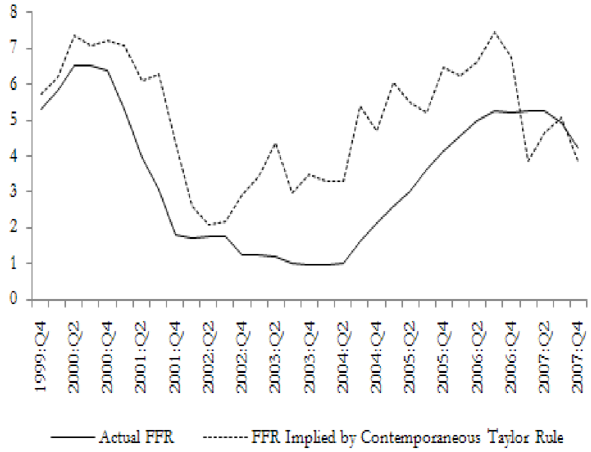
	U.S.				Euro Area			
	Mean	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*
A. Revised Data								
Revised Inflation	2.68	0.78	1.16	4.08	2.09	0.35	1.23	3.06
Revised HP Filtered Output Gap	-0.05	2.11	-3.41	4.96	0.07	1.80	-2.54	4.00
Revised OECD Output Gap	-0.03	1.05	-1.61	2.05	-0.08	1.36	-1.76	2.33
Revised Unemployment Rate	5.00	0.69	3.90	6.10	8.40	0.49	7.40	9.10
B. Real-Time Data								
Real-Time Inflation	2.67	0.78	1.12	4.08	2.14	0.40	1.16	3.34
Revised HP Filtered Output Gap	-1.19	1.76	-5.55	0.56	0.18	1.20	-2.11	2.05
Real-Time OECD Output Gap	0.02	1.48	-2.27	3.20	-1.22	0.79	-2.46	0.12
Real-Time Unemployment Rate	5.01	0.68	4.00	6.10	8.54	0.68	6.90	10.20

Note: The statistics reported for each variable are: Mean, the mean, SD, the standard deviation, Min, and Max, the minimum and maximum values. The data is for 1999:Q4-2007:Q4.

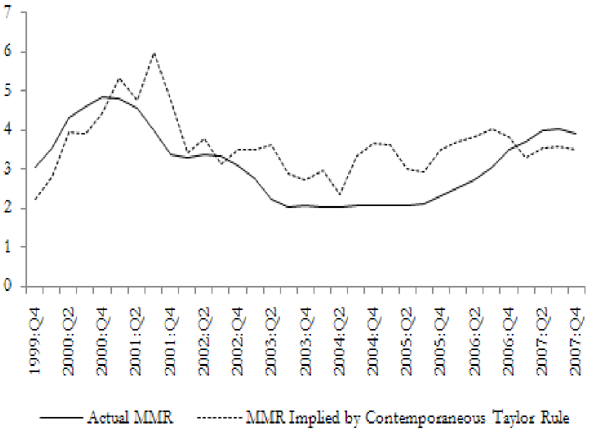
Table 2. Descriptive Statistics of Revisions

	U.S.					Euro Area				
$X_{Revised}$–$X_{Real\text{-}time}$	*Mean*	*SD*	*NORM*	*Corr with $X_{Revised}$*	*Corr with $X_{Real\text{-}time}$*	*Mean*	*SD*	*NORM*	*Corr with $X_{Revised}$*	*Corr with $X_{Real\text{-}time}$*
Inflation	0.01	0.06	0.03	0.15	0.08	-0.05	0.15	0.00	-0.15	-0.50
HP Filtered Output	1.14	1.96	0.21	0.63	-0.36	-0.11	1.34	0.32	0.75	0.01
OECD Output Gap	-0.05	0.58	0.11	-0.62	-0.83	1.13	0.85	0.22	0.84	0.36
Unemployment Rate	-0.01	0.06	0.00	0.16	0.25	-0.13	0.50	0.34	0.05	-0.69

Note: The statistics reported for each variable are: Mean, the mean, SD, the standard deviation, NORM, the p-values for normality test, Corr with $X_{Revised}$, Corr with $X_{Real\text{-}time}$ are correlations of revisions with revised of real-time series. Positive and significant value of the "mean" revision indicates that the variable was consistently revised upwards.

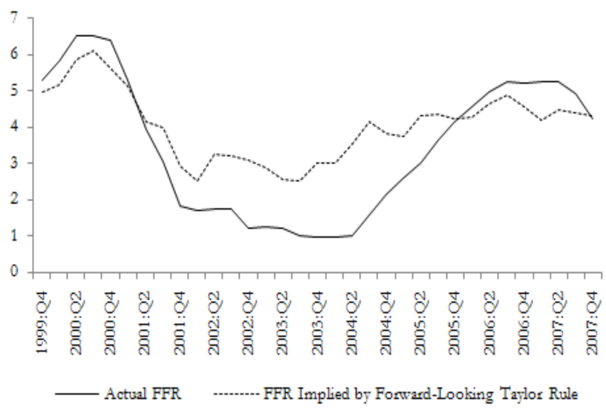


United States

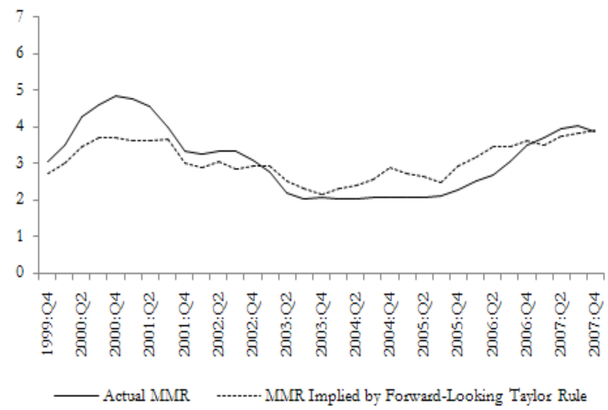


Euro Area

A. Contemporaneous Taylor Rule with the Equilibrium Real Interest Rate Set at 2%

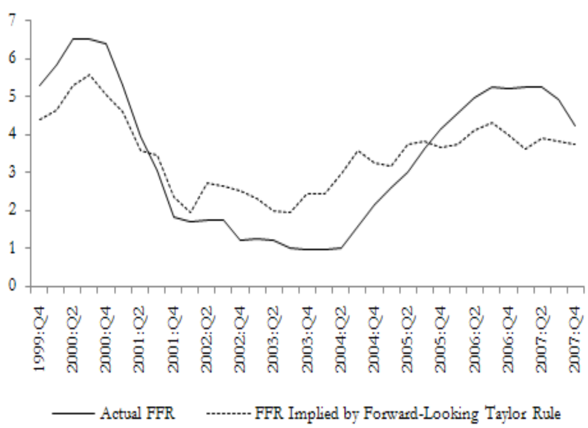


United States

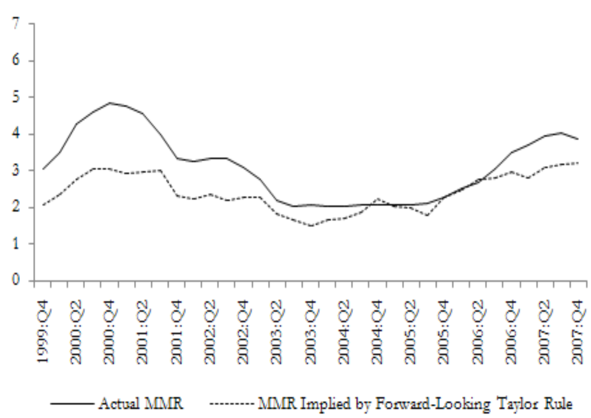


Euro Area

B. Forward-Looking Taylor Rule with the Equilibrium Real Interest Rate Set at 2%



United States



Euro Area

C. Forward-Looking Taylor Rule with a Calculated Equilibrium Real Interest Rate

Figure 2. Actual and Counterfactual Interest Rates for the U.S. and Euro Area

Table 3: One-Quarter-Ahead Out-of-Sample Forecasts with Real-Time Data

	w/o Smoothing		*w/ Smoothing*	
	Symmetric	*Asymmetric*	*Symmetric*	*Asymmetric*
A. Homogenous Coefficients				
HP Filtered Output Gap	2.453***	1.927**	2.051***	0.591
OECD Estimates of Output Gap	1.848**	1.434*	1.321*	-0.688
Unemployment Rate	2.667***	1.910**	2.407***	0.310
B. Heterogeneous Coefficients				
HP Filtered Output Gap	2.025***	1.001	2.165***	0.026
OECD Estimates of Output Gap	2.218***	1.577*	1.734**	-0.207
Unemployment Rate	2.356***	0.725	1.909**	0.110

Notes to Tables 1-5:

1. The tables report CW statistics for tests of equal predictive ability between the null of a martingale difference process and the alternative of a linear model with Taylor rule fundamentals. * ,**, and *** denote test statistics significant at 10, 5, and 1% level, respectively, based on standard normal critical values for the one-sided test.
2. The HP-filtered output gap is calculated using data from 1990:Q1. Before applying the filter, we forecast and backcast the industrial production series by 12 quarters in both directions assuming that growth rates follow an AR(4) process. Internal OECD estimates of the output gap for the U.S. and Euro Area are from the semi-annual issues of OECD Economic Outlook. The reported estimates and forecasts of annual output gaps are transformed into quarterly using quadratic interpolation.
3. For each forecasting regression, we start in 1991:Q1 and use a window of 34 quarters to estimate the historical relationship between the Taylor rule fundamentals and the change in the exchange rate, and then use the estimated coefficients to forecast the exchange rate one-quarter-ahead. We use rolling regressions to predict 32 exchange rate changes from 2000:Q1 to 2007:Q4.
4. The forward looking specifications use the Philadelphia Fed Survey of Professional Forecasters (SPF) forecast data for the U.S. during the whole sample. For the Euro Area, the first round of the survey was conducted in 1999:Q1. To construct the t+4 inflation forecast for any vintage, we use the realized t+4 values of inflation (which is sometimes interpreted as the "rational" t+4 forecast of inflation) before 1998:Q4 and real-time Euro Area SPF forecasts from 1999:Q1 to 2007:Q4.

Table 4: One-Quarter-Ahead Out-of-Sample Forecasts with Real-Time Data and Either Inflation or the Output Gap

	w/o Smoothing		*w/ Smoothing*	
	Symmetric	*Asymmetric*	*Symmetric*	*Asymmetric*
A. Homogenous Coefficients				
HP Filtered Output Gap	2.193***	1.125	2.003***	0.531
OECD Estimates of Output Gap	2.005***	0.802	1.574*	-0.782
Unemployment Rate	3.110***	2.175***	2.156***	-0.015
Inflation	1.936**	1.317*	1.607*	0.168
B. Heterogeneous Coefficients				
HP Filtered Output Gap	2.166***	1.216	2.035***	0.592
OECD Estimates of Output Gap	2.255***	1.250	1.753**	-0.910
Unemployment Rate	2.491***	1.620*	1.964***	-0.186
Inflation	1.901**	1.271	1.565*	-0.289

Table 5: One-Quarter-Ahead Out-of-Sample Forecasts with Revised Data

	w/o Smoothing		*w/ Smoothing*	
	Symmetric	*Asymmetric*	*Symmetric*	*Asymmetric*
A. Homogenous Coefficients				
HP Filtered Output Gap	2.650***	1.981***	1.705**	0.396
OECD Estimates of Output Gap	1.488*	1.255	1.215	-0.115
Unemployment Rate	2.232***	1.719**	1.968**	0.051
B. Heterogeneous Coefficients				
HP Filtered Output Gap	2.297***	2.137***	1.909**	0.896
OECD Estimates of Output Gap	1.401*	1.433*	1.297*	0.221
Unemployment Rate	2.230***	0.919	1.579*	0.250

Note: The revised data is constructed from the 2007:Q4 vintage for both the U.S. and the Euro Area.

Table 6: One-Quarter-Ahead Out-of-Sample Forecasts with Real-Time Data and t+4 Inflation Forecasts

	w/o Smoothing		*w/ Smoothing*	
	Symmetric	*Asymmetric*	*Symmetric*	*Asymmetric*
A. Homogenous Coefficients				
HP Filtered Output Gap	2.315***	1.235	2.088***	0.969
OECD Estimates of Output Gap	1.918**	1.131	2.004***	0.525
Unemployment Rate	3.565***	2.791***	2.372***	0.100
B. Heterogeneous Coefficients				
HP Filtered Output Gap	2.428***	0.210	2.246***	0.647
OECD Estimates of Output Gap	1.943**	1.064	1.879**	-0.221
Unemployment Rate	2.593***	0.392	1.439*	-0.896

Table 7: One-Quarter-Ahead Out-of-Sample Forecasts with Real-Time Data,

t+4 Inflation Forecasts and Output Gap Growth

	w/o Smoothing		*w/ Smoothing*	
	Symmetric	*Asymmetric*	*Symmetric*	*Asymmetric*
A. Homogenous Coefficients				
HP Filtered Output Gap	-0.243	-0.711	0.928	-0.062
OECD Estimates of Output Gap	0.997	-0.831	1.483*	-0.495
Unemployment Rate	2.754***	2.057***	1.209	-0.334
B. Heterogeneous Coefficients				
HP Filtered Output Gap	0.773	-0.163	1.266	0.217
OECD Estimates of Output Gap	1.995***	0.038	1.029	-2.077
Unemployment Rate	1.669**	0.324	0.816	-0.666

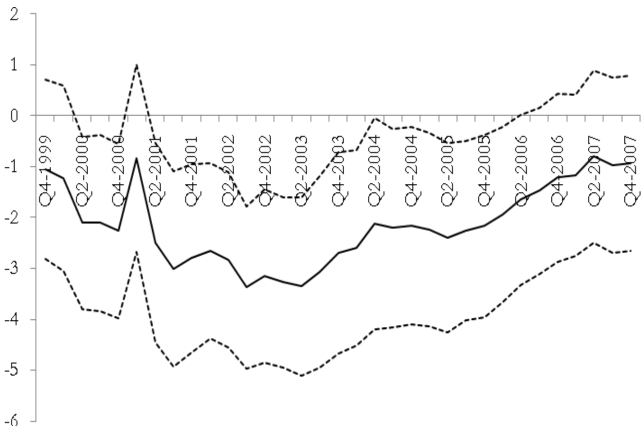
Note: Forecasted OECD output gap growth is calculated as the difference between the forecasted OECD output gap in time (t+4) and the current OECD output gap.

Table 8: Tests for Superior Predictive Ability

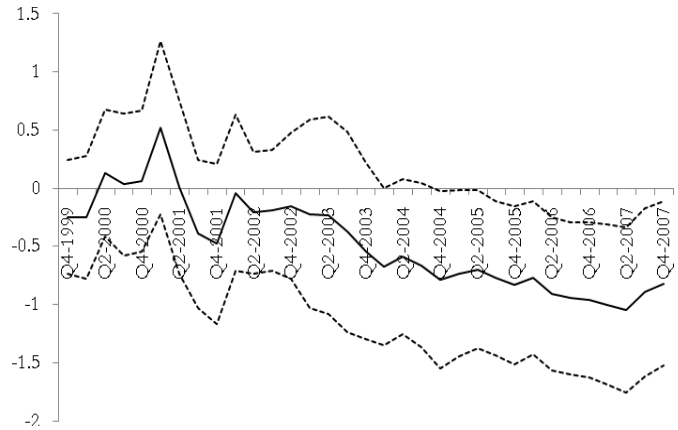
Models	*Sym*	*Asym*
Homogenous w/ Smoothing	0.023**	0.470
Homogenous w/o Smoothing	0.016**	0.074*
Heterogenous w/ Smoothing	0.034**	0.679
Heterogenous w/o Smoothing	0.030**	0.153
Homogenous	0.021**	0.128
Heterogenous	0.039**	0.219
Smoothing	0.031**	0.605
No Smoothing	0.021**	0.106
All	0.028**	0.179

Notes:

1. The table reports SPA p-values for nine sets of forecasts based on symmetric (*Sym*) and asymmetric (*Asym*) Taylor rule specifications that are compared to a random walk forecast.
2. Each row contains the results for the following classes of models: All, all Taylor rule models, Smoothing and No Smoothing, models that include or exclude interest rate smoothing, Homogenous and Heterogeneous, models that restrict or do not restrict the coefficients on inflation and measures of economic activity to be the same for the U.S. and Euro Area.

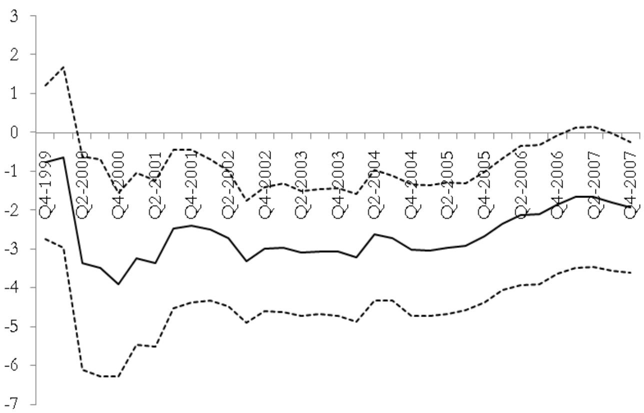


Inflation Differential Coefficient

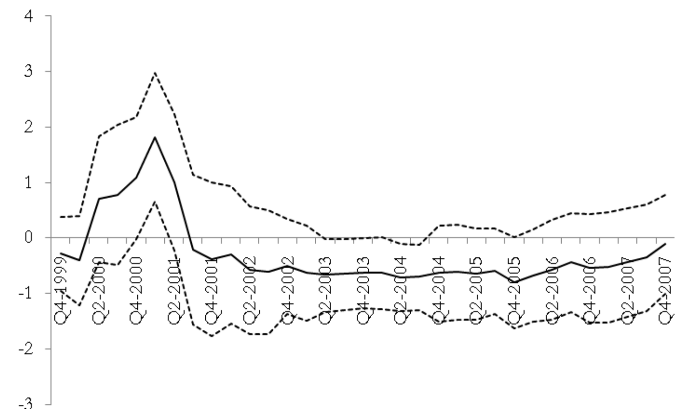


Output Gap Differential Coefficient

A. Homogeneous Specification with HP Filtered Output Gap

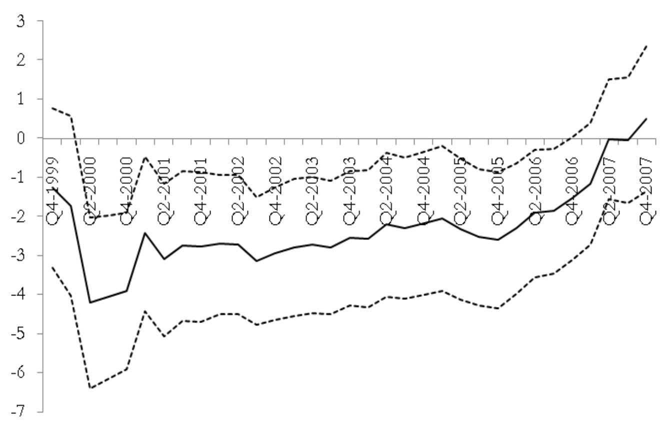


Inflation Differential Coefficient

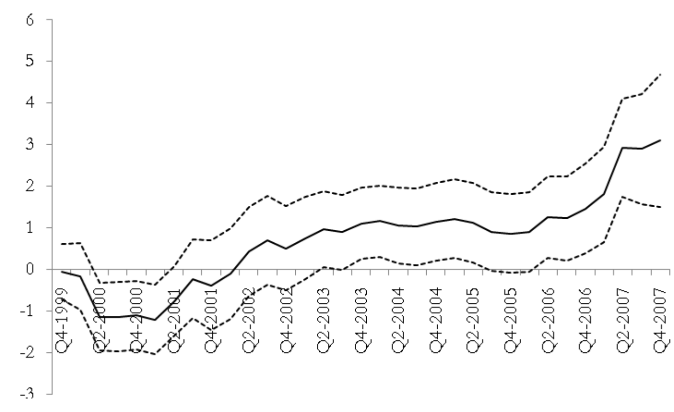


Output Gap Differential Coefficient

B. Homogeneous Specification with OECD Estimates of Output Gap



Inflation Differential Coefficient



Unemployment Differential Coefficient

C. Homogeneous Specification with Unemployment Rate

Figure 3. Dynamics of Forecasting Equation Coefficients