Taylor Rule Deviations and Out-of-Sample Exchange Rate Predictability

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Abstract

The Taylor rule has become the dominant model for academic evaluation of out-of-sample exchange rate predictability. Two versions of the Taylor rule model are the Taylor rule fundamentals model, where the variables that enter the Taylor rule are used to forecast exchange rate changes, and the Taylor rule differentials model, where a Taylor rule with postulated coefficients is used in the forecasting regression. We use data from 1973 to 2014 to evaluate short-run out-of-sample predictability for eight exchange rates vis-à-vis the U.S. dollar, and find strong evidence in favor of the Taylor rule fundamentals model alternative against the random walk null. The evidence of predictability is weaker with the Taylor rule differentials model, and still weaker with the traditional interest rate differential, purchasing power parity, and monetary models. The evidence of predictability for the fundamentals model is not related to deviations from the original Taylor rule for the U.S., but is related to deviations from a modified Taylor rule for the U.S. with a higher coefficient on the output gap. The evidence of predictability is also unrelated to deviations from Taylor rules for the foreign countries and adherence to the Taylor principle for the U.S.

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1. Introduction

The Taylor rule has become the dominant model for academic evaluation of out-of-sample exchange rate predictability. Papers by Engel, Mark, and West (2008, 2015), Molodtsova and Papell (2009, 2013), Molodtsova, Nikolsko-Rzhevskyy, and Papell (2008, 2011), and Ince (2014) report superior out-of-sample exchange rate predictability with Taylor rule models than with the random walk model. Rossi (2013) surveys the literature and concludes that Taylor rule models perform better than a number of alternatives.

Out-of-sample exchange rate forecasting became a prominent academic topic following Meese and Rogoff (1983), who argued that empirical exchange rate models which appeared to fit well in-sample did not forecast better than a random walk out-of-sample. Their metric was the root mean squared forecast error (RMSE), where the forecast error is the difference between the realized and forecasted exchange rate for the models and, since a random walk forecast is simply a naïve no change forecast, the realized exchange rate change for the random walk. Because the random walk forecast could be performed by anyone who read a newspaper, this received considerable attention.

The first "modern" analysis of out-of-sample exchange rate forecasting was by Mark (1995), who used error correction methods to evaluate Purchasing Power Parity (PPP), Interest Rate Parity (IRP), and monetary models vis-à-vis the random walk model with DMW statistic developed by Diebold and Mariano (1995) and West (1996). Mark found that, while some evidence of predictability could be found at long horizons of up to four years, no systematic evidence of predictability could be found at short horizons of one quarter. While the long-horizon results have been both criticized and confirmed, the short-horizon results have held up over time. In a comprehensive paper, Cheung, Chinn, and Pascual (2005) found that none of the standard models could systematically forecast better than the random walk at short time horizons.

Out-of-sample exchange rate predictability with Taylor rule fundamentals was initiated by Molodtsova and Papell (2009). The idea is to subtract a Taylor rule for the foreign country from a Taylor rule for the domestic country, in this case the United States. The resultant equation has the interest rate differential on the left-hand-side and the variables that comprise the Taylor rule, domestic and foreign inflation, output gaps, and (depending on the specification) lagged interest rates and/or the real exchange rate, on the right-hand-side. If uncovered interest rate parity (UIRP) held in the short run, you would simply replace the interest rate differential with the expected rate of depreciation to derive a forecasting equation. However, there is overwhelming evidence, both theoretical and empirical, that UIRP not only does not hold in the short run, but that the short-run effects are opposite of the UIRP predictions. The resultant forecasting equation, therefore, reverses the signs of the coefficients of the right-hand-side variables from what would be predicted by UIRP. Using the CW statistic developed by Clark and West (2006), Molodtsova and Papell (2009) report statistically significant evidence of exchange rate predictability at the 5 percent level for 11 of the 12 currencies studied at the one-month-ahead horizon.

An alternative model of out-of-sample exchange rate predictability with Taylor rules was developed by Engel, Mark, and West (2008). They subtract the Taylor rule for the base country from the Taylor rule for the foreign country, but use posited rather than estimated coefficients and include the real exchange rate in the forecasting equation. We call this the Taylor rule differentials model. They use both single-equation and panel methods at one quarter and 16 quarter-ahead horizons, and report some evidence of out-of-sample predictability using the CW statistic. They find stronger evidence at the 16-quarter than at the one-quarter horizon and stronger evidence when the random walk with drift is used for the null hypothesis instead of the random walk without drift. Ince (2014) uses their methods with real-time data and reports somewhat stronger results.

The financial crisis, Great Recession, and slow recovery for the U.S. raise questions about whether Taylor rule exchange rate forecasting is still relevant in an environment where the federal funds rate has been at the zero lower bound from the end of 2008 through the end of 2014. As early as December 2008, Chinn (2008) posed this question, concluding that, with policy rates near zero for Japan and the U.S. and predicted to be near-zero for the United Kingdom and the Euro Area, prospects for continued Taylor rule exchange rate forecasting were bleak. A second theme, however, was that returning to the monetary model, even in a time of quantitative easing, did not seem promising. Molodtsova and Papell (2013) used LIBOR-OIS spreads, TED spreads, Bloomberg financial conditions indexes, and OECD financial conditions indexes for the U.S. and the Euro Area to augment Taylor rule exchange rate forecasting for the dollar/euro exchange rate from 2007:Q1 to 2012:Q1. The Taylor rule fundamentals and differentials models with financial variables provided more evidence of out-of-sample exchange rate predictability than the models without financial variables.

This paper has two objectives. The first is to update the analysis in Molodtsova and Papell (2009) and see whether the results hold up when the data is extended through 2014. We investigate out-of-sample exchange rate predictability with Taylor rule models for U.S. dollar exchange rates for seven non-euro countries that were considered by Molodtsova and Papell (2009), Australia, Canada, Denmark, Japan, Sweden, Switzerland, and the United Kingdom. Because we are interested in the recent period, we do not consider the Euro countries, France, Italy, Netherlands, and Portugal, but include the deutsche mark/euro exchange rate for Germany.

We estimate 20 specifications of the Taylor rule fundamentals model. Four classes of the model, with heterogeneous or homogenous coefficients on inflation and the output gap for the U.S. and the foreign country and the model with or without the real exchange rate, are estimated using five specifications. One of the models does not allow for interest rate smoothing and, therefore, does not include lagged interest rates. Among the four specifications with smoothing, two include the lagged interest rate differential and two include individual lagged interest rates. The second division is that two models with smoothing incorporate the federal funds rate for the U.S. and the other two models use a measure of the shadow federal funds rate, the policy rate adjusted to incorporate the effects of quantitative easing and forward guidance, from 2009 to 2014. All of the models include a constant.

Out-of-sample exchange rate predictability with Taylor rule fundamentals does not fall apart after the financial crisis. Overall, the models with heterogeneous coefficients provide substantially more evidence of predictability than the models with homogeneous coefficients. The models that do not include real exchange rate, which we call symmetric, provide more evidence of predictability than the models that include exchange rate targeting, which we call asymmetric. As in Molodtsova and Papell (2009), the Taylor rule fundamentals models that produce the strongest evidence of exchange rate predictability are the models with heterogeneous coefficients that include interest rate smoothing and don't include the real exchange rate. For that model with the five Taylor rule fundamentals specifications, the no predictability null of the random walk model without drift can be rejected in favor of the Taylor rule fundamentals model at the 1 percent level for 4 of the 8 countries for all specifications, at the 5 percent level for 3 additional countries for at least three specifications, and at the 10 percent for the remaining country for three specifications out of five.

We find much less evidence of out-of-sample exchange rate predictability with the Taylor rule differentials model. We estimate 15 specifications, the original Taylor (1993) rule, a modified Taylor rule with a higher output gap coefficient for both the U.S. and the foreign country, and a hybrid Taylor rule with a higher output gap coefficient only for the U.S., for each of the five models described above. The most successful results are for models with smoothing where individual lagged interest rates and the shadow federal funds rate were used. For this model, the no predictability null can be rejected for 4 of the 8 countries with the original and modified Taylor rules, and for 5 of the 8 countries with the hybrid Taylor rule model. The conventional exchange rate models fare even worse. The no predictability null can be rejected for 3 of the 8 countries with the interest rate model that incorporates the shadow federal funds rate, 2 out of 8 countries with the interest rate model that uses the money market rate, 2 out of 8 countries with the monetary model that assumes the coefficient on relative output equal to 0, 1 out of 8 countries with the monetary model that sets the coefficient on relative output equal to 1, and no countries with the PPP model.

The second objective of the paper is to investigate whether out-of-sample exchange rate predictability with Taylor rule fundamentals is stronger during the periods in which adherence to the Taylor rule is closer. This question arises because, since the Taylor rule fundamentals model includes the variables that enter in the Taylor rule, but does not constrain their coefficients, it is possible to find evidence of predictability that is unrelated to adherence to the Taylor rule. Molodtsova and Papell (2009) addressed this by examining the coefficients on U.S. and foreign inflation in the forecasting regressions but, as shown by Nikolsko-Rzhevskyy, Papell, and Prodan (2015), there is not a one-to-one correspondence between the coefficient on inflation and adherence to the Taylor rule.

Nikolsko-Rzhevskyy, Papell, and Prodan (2014) estimate structural change models on Taylor rule deviations, the absolute value of the difference between the federal funds rate and the rate prescribed by the original Taylor rule, for the U.S. using real-time data, and identify periods of high and low deviations. Over the span of data for which we conduct out-of-sample exchange rate forecasts, 1985:M4 – 2000:M12 is a low deviations era and 2001:M1 – 2014:M12 is a high deviations era. We divide the sample between high and low deviations periods, and calculate CW statistics for each period. The results are not supportive of the hypothesis that out-of-sample exchange rate predictability is related to adherence to the original Taylor rule, as the evidence against the no predictability null is stronger for the high deviations eras for four countries, mixed for three countries, and stronger for the low deviations era for one country.

We next consider modified Taylor rule deviations, the absolute value of the difference between the federal funds rate and the rate prescribed by the modified Taylor rule, which are also calculated by Nikolsko-Rzhevskyy, Papell, and Prodan (2014). Over the span of data for which we conduct out-of-sample exchange rate forecasts, 1985:M1 – 1999:M3 and 2006:M10 – 2014:M12 are low deviations eras and 1999:M4 – 2006:M9 is a high deviations era. The congruence between finding evidence of out-of-sample predictability and being in a low deviations era is much greater for the modified Taylor rule than for the original Taylor rule. The evidence against the no predictability null hypothesis is stronger for the low deviations eras for seven countries and mixed for one country. Among the models, the differential is larger for the smoothing models and somewhat larger for the models with the shadow federal funds rate.

Although the Taylor rule fundamentals model incorporates both U.S. and foreign variables, the high and low deviations eras used above are defined solely in terms of U.S. deviations. Teryoshin (2014) uses the methods in Nikolsko-Rzhevskyy, Papell, and Prodan (2014) to calculate original and modified Taylor rule deviations for six countries in our sample: Australia, Canada, Japan, Sweden, Switzerland, and the United Kingdom. There is not much congruence between finding evidence of out-of-sample predictability and being in a low deviations era for either the original or the modified Taylor rule.

Monetary policy analysis using Taylor rules is typically conducted in terms of the Taylor principle that the nominal interest rate should increase by more than point-for-point when inflation rises so that the real interest rate increases. Nikolsko-Rzhevskyy, Papell, and Prodan (2015) estimate Taylor rules for the U.S. over monetary policy eras defined by several Taylor rule variants. Within our sample, the Taylor principle holds from 1983:M3 – 1999:M3 because the coefficient on inflation is significantly greater than one, the evidence is mixed from 1999:M4 – 2007:M6 because the coefficient on inflation is greater than one but not significant, and the Taylor principle fails to hold from 2007:M7 – 2014:M12 because the coefficient on inflation is less than one. Adherence to the Taylor principle, however, is not positively correlated with finding evidence of out-of-sample predictability, as the evidence of predictability is stronger during eras where the Taylor principle does not hold for four countries and stronger during eras where the Taylor principle holds for only one country.

The relation between Taylor rule deviations and out-of-sample exchange rate predictability closely follow Fed policy as articulated by Yellen (2012). The strongest results are for deviations calculated from a modified Taylor rule with a specification incorporating interest rate smoothing that reflects quantitative easing and forward guidance. In contrast, strong results are not obtained from deviations calculated from the original Taylor rule and foreign Taylor rules, or from monetary policy eras based on adherence to the Taylor principle instead of the Taylor rule.

2. Exchange Rate Forecasting Models

2.1 Taylor Rule Fundamentals Model

We examine the linkage between the exchange rates 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

$$\bar{i}_t = \pi_t + \phi(\pi_t - \bar{\pi}) + \gamma y_t + \bar{r} \tag{1}$$

where $\bar{i}_t$ is the target for the short-term nominal interest rate, π_t is the inflation rate, $\bar{\pi}$ 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 $\bar{r}$ 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.

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 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 $\bar{\pi}$ and $\bar{r}$ in equation (1) can be combined into one constant term $\mu = \bar{r} - \phi\bar{\pi}$, which leads to the following equation,

$$\bar{i}_t = \mu + \lambda\pi_t + \gamma y_t \tag{2}$$

where $\lambda = 1 + \phi$. Because $\lambda > 1$, the real interest rate is increased when inflation rises and so the Taylor principle is satisfied.

Following Clarida, Gali, and Gertler (1998), it has become common practice to specify variants of the Taylor rule which allow for the possibility that the interest rate adjusts gradually to achieve its target level and/or include the real exchange rate in addition to inflation and the output gap. The rationale for including the real exchange rate 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. We assume that the actual observable interest rate i_t partially adjusts to the target as follows:

$$i_t = (1-\rho)\bar{i}_t + \rho i_{t-1} + v_t \tag{3}$$

Substituting (2) into (3) gives the following equation,

$$i_t = (1-\rho)(\mu + \lambda\pi_t + \gamma y_t + \delta q_t) + \rho i_{t-1} + v_t \tag{4}$$

where q_t is the real exchange rate.

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

$$i_t - i_t^* = \alpha + \alpha_{u\pi}\pi_t - \alpha_{f\pi}\pi_t^* + \alpha_{uy}y_t - \alpha_{fy}y_t^* - \alpha_q q_t^* + \rho_u i_{t-1} - \rho_f i_{t-1}^* + \eta_t \tag{5}$$

where * denotes foreign variables, *u* and *f* are coefficients for the United States and the foreign country. Although equation (5) only includes the real exchange rate in the Taylor rule for the foreign country, this specification would be unchanged if the U.S. also had an exchange rate target in its interest rate reaction function.[1]

Based on empirical research on the forward premium and delayed overshooting puzzles by Eichenbaum and Evans (1995), Faust and Rogers (2003) and Scholl and Uhlig (2008), and the results in Gourinchas and Tornell (2004) and Bacchetta and van Wincoop (2010), who show that an increase in the interest rate can cause sustained exchange rate appreciation if investors either systematically underestimate the persistence of interest rate shocks or make infrequent portfolio decisions, we postulate the following exchange rate forecasting equation:[2]

[1] This was shown by Engel and West (2005).
[2] A more extensive discussion can be found in Molodtsova and Papell (2009).

$$\Delta e_{t+1} = \omega - \omega_{u\pi}\pi_t + \omega_{f\pi}\pi_t^* - \omega_{uy}y_t + \omega_{fy}y_t^* + \omega_q q_t^* - \omega_{ui}i_{t-1} + \omega_{fi}i_{t-1}^* + \eta_t \tag{6}$$

The variable e_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 e_t is a depreciation of the dollar. The reversal of the signs of the coefficients between (5) and (6) reflects the presumption that anything that causes the Fed and/or other central banks to raise the U.S. interest rate relative to the foreign interest rate will cause the dollar to appreciate (a decrease in e_t). Since we do not know by how much a change in the interest rate differential will cause the exchange rate to adjust, we do not have a link between the magnitudes of the coefficients in (5) and (6).

2.2 Taylor Rule Differentials Model

Engel, Mark, and West (2008, 2015) propose an alternative Taylor rule based model, which we call the Taylor rule differentials model to differentiate it from both the interest rate differentials model and the Taylor rule fundamentals model. The difference between the Taylor rule differentials and fundamentals models is that the former posits, rather than estimates, the coefficients for the Taylor rule. Using Taylor's original coefficients and subtracting the interest rate reaction function for the foreign country from that for the U.S., we obtain implied interest rate differentials,

$$i_t - i_t^* = a + 1.5(\pi_t - \pi_t^*) + 0.5(y_t - y_t^*) \tag{7}$$

where α is a constant.[3]

The implied interest rate differential can be used to construct an exchange rate forecasting equation,

$$\Delta e_{t+1} = \omega - \omega_i(1.5(\pi_t - \pi_t^*) + 0.5(y_t - y_t^*)) + \eta_t \tag{8}$$

where, as in the Taylor rule fundamentals model, the signs of the coefficients are assumed to switch and we do not have a link between the magnitudes of the coefficients in (7) and (8).

Rudebusch (2010) and Yellen (2012) argue that the appropriate output gap coefficient in the Taylor rule for the U.S. should be double the coefficient in Taylor's original rule. While there has been an active policy debate on the normative question of whether prescribed Taylor rule interest rates should be calculated using Taylor's original specification or with larger

[3] Engel, Mark, and West (2008) use single equation and panel models with coefficients of 2.0 on inflation, 0.5 on the output gap, and 0.1 on the real exchange rate. Engel, Mark, and West (2015) use panel models that incorporate exchange rate factors with Taylor's original coefficients.

coefficients, it is clear that the latter provide a better fit for Fed policy in the 2000s. In order to differentiate this rule from the original Taylor rule, we call it the modified Taylor rule and incorporate the higher output gap coefficient in the forecasting equation,

$$\Delta e_{t+1} = \omega - \omega_i (1.5(\pi_t - \pi_t^*) + 1.0(y_t - y_t^*)) + \eta_t \quad (9)$$

Since the same argument has not typically been made for the other countries in our sample, we also estimate a hybrid Taylor rule differentials model with a coefficient of 1.0 on the U.S. output gap and 0.5 on foreign output gap,

$$\Delta e_{t+1} = \omega - \omega_i (1.5(\pi_t - \pi_t^*) + 1.0 y_t - 0.5 y_t^*) + \eta_t \quad (10)$$

The forecasting equations for the Taylor rule fundamentals and differentials models include a constant term. The absence of a constant would require the equilibrium real interest rates, target inflation, and the coefficients on inflation to be identical in the two countries. Since there is no empirical evidence to support this for the countries in our sample, we include a constant in all Taylor rule specifications.[4]

2.3 Interest Rate Differentials Model

We postulate the following exchange rate forecasting equation,

$$\Delta e_{t+1} = \omega - \omega_i (i_t - i_t^*) \quad (11)$$

where e_t is the exchange rate, i_t is the domestic interest rate, i_t^* is the foreign interest rate, and an increase in the domestic interest rate relative to the foreign interest rate produces forecasted exchange rate appreciation. This is not consistent with uncovered interest rate parity (UIRP), where ω_i would equal one, but it is consistent with the carry trade literature and with the empirical evidence in Chinn (2006), who shows that, while UIRP may hold in the long-run, it clearly does not hold in periods of less than one year. This is the exchange rate forecasting equation used by Clark and West (2006). While they did not specify a sign for ω_i, their successful results were consistent with a negative coefficient.

2.4 Monetary and Purchasing Power Parity Fundamentals Models

Following Mark (1995), most widely used approach to evaluating exchange rate models out of sample is to represent a change in (the logarithm of) the nominal exchange rate as a function of its deviation from its fundamental value. Thus, the one-period-ahead change in the

[4] Taylor rule fundamentals models without a constant produced much less evidence of predictability than the models with a constant in Molodtsova and Papell (2009).

log exchange rate can be modeled as a function of its current deviation from its fundamental value.

$$\Delta e_{t+1} = \omega + \omega_z z_t + \nu_t , \tag{12}$$

where $z_t = f_t - e_t$

and f_t is the long-run equilibrium level of the nominal exchange rate determined by macroeconomic fundamentals.

The monetary fundamentals model specifies exchange rate behavior in terms of relative demand for and supply of money in the two countries. Assuming purchasing power parity, UIRP, and no rational speculative bubbles, the fundamental value of the exchange rate can be derived.

$$f_t = (m_t - m_t^*) - k(y_t - y_t^*) \tag{13}$$

where m_t and y_t are the logs of money supply and income in period *t*; asterisks denote foreign country variables. We construct the monetary fundamentals with a fixed value of the income elasticity, *k*, which can equal to 0 or 1. We substitute the monetary fundamentals (13) into (12), and use the resultant equation for forecasting.

The Purchasing Power Parity (PPP) fundamentals model postulates that the exchange rate will adjust over time to eliminate deviations from long-run PPP. Under PPP fundamentals,

$$f_t = (p_t - p_t^*) \tag{14}$$

where p_t is the log of the national price level. We substitute the PPP fundamentals (14) into (12), and use the resultant equation for forecasting.

3. Forecasting and Predictability

When Meese and Rogoff wrote their paper, the statistical methodology for evaluating whether a smaller RMSE was significantly different from a larger RMSE did not exist. Meese and Rogoff (1983) recognized this, reported that the RMSEs from the models were almost all larger than the RMSEs from the random walk, and stated that, while they could conclude that the forecasts from the models were not superior to those from the random walk, they could not conclude that the forecasts from the random walk were superior to those from the models. It was not until more than a decade later that Diebold and Mariano (1995) and West (1996) developed the methodology, known jointly as the DMW statistic, to evaluate the significance of the difference between larger and smaller RMSEs.

An important issue with the applicability of DMW tests to out-of-sample exchange rate forecasting is that they are only applicable to non-nested models where the variables in one model are not a subset of the variables in the other model. Since the random walk model contains no right-hand-side variables, it is nested in all linear models. What exacerbates the problem is that, if the null hypothesis is correct and the exchange rate is a random walk, estimates of linear models with (extraneous) right-hand-side variables will have higher RMSEs than the random walk model. Since the RMSEs should be equal under the null, this produces undersized tests which will not reject often enough. The magnitude of the problem was documented by McCracken (2007), who showed that using standard normal critical values for the DMW statistic results in tests with nominal size of 0.10 generally having actual size of less than 0.02.

Clark and West (2006) propose an adjustment to the DMW statistic, called the CW statistic, which adjusts the DMW statistic to achieve correct size with standard normal critical values. With the DMW test, the null hypothesis is that the two models have the same RMSE, while the alternative hypothesis is that the RMSE of the linear model is smaller than the RMSE of the random walk model. With the CW test, the null hypothesis is that the regression coefficients in the linear model equal zero so that the exchange rate follows a random walk, while the alternative hypothesis is that the regression coefficients are different from zero so that the exchange rate can be described by a linear model. It is possible, therefore, to reject the random walk null in favor of the linear model even if the RMSE is smaller for the random walk than for the linear model. That is why these methods are tests of predictability, not of forecasting ability, as they are not minimum RMSE tests.[5] The CW statistic has become the standard method to test exchange rate models out-of-sample, and was used by Engel, Mark, and West (2008, 2015) and Molodtsova and Papell (2009, 2013).

4. Out-of-Sample Exchange Rate Predictability

The models are estimated using monthly data from March 1973 through December 2014 for seven non-euro countries that were considered by Molodtsova and Papell (2009); Australia,

[5] Rogoff and Stavrakeva (2008) criticize the use of CW tests because they are not minimum RMSE tests.

Canada, Denmark, Japan, Sweden, Switzerland, and the United Kingdom, as well as Germany.[6] Our choice of countries is dictated by our intention to examine exchange rate behavior for major currencies over the recent period. The exchange rate is defined as the domestic currency (U.S. dollar) price of a unit of foreign currency, so that an increase in the exchange rate is a depreciation of the dollar.

4.1 Data

The primary source of data is the IMF's *International Financial Statistics* (IFS) database. We update the data in Molodtsova and Papell (2009) until December 2014, preserving the same variable definitions. The price level in the country is measured by consumer price index (IFS line 64). The inflation rate is the annual inflation rate, measured as the 12-month percentage difference of the CPI. We use seasonally adjusted industrial production index as a measure of a country's economic activity. We use M1 to measure the money supply for all countries, except the U.K. for which M0 is used because M1 data is unavailable.

The output gap is estimated as a percentage deviation of actual output from a quadratic time trend. In order to mimic the real-time forecasting environment as closely as possible when real-time data is unavailable, we use quasi-real-time output gap estimation, where only the data points up to period *t-1* are used to construct the trend for a given period *t*. Orphanides and van Norden (2002) find that the correlations between real-time and revised output gap estimates are low while the correlations between real-time and quasi-real-time output gap estimates are high for the U.S. Ince and Papell (2013) extend their findings for the U.S. to 9 additional OECD countries, 6 of which are included in our sample. These results suggest that most of the difference between real-time and revised output gap estimates comes from using ex-post data to estimate the trend, not from the revisions themselves, and reliable output gap estimates can be constructed with quasi-real-time data when real-time data is unavailable.

We use the money market rate (IFS line 60B) as a measure of the short-term interest rate that the central bank sets every period. The money market rate for the U.S. is the federal funds rate (FFR). Alternatively, we replace the FFR for the U.S. with the Wu and Xia (2014) shadow FFR after 2009:M1. The shadow rate is a better measure of the policy interest rate when the FFR is constrained by a zero lower bound. The shadow rates are calculated using a nonlinear term

[6] Some of the models are estimated using shorter time spans of data because of data unavailability. The footnotes for the tables list these exceptions.

structure model and are consistently negative from July 2009 onward.[7] The exchange rates are end-of-month nominal exchange rates from the Federal Reserve Bank of Saint Louis database. The exchange rate for Germany after 1998 is replaced with a synthetic Deutsche mark/dollar rate, which is calculated, as in Engel, Mark, and West (2008) and Ince (2014), using the rate of depreciation of the dollar/Euro rate.

4.2 Forecasts

We evaluate one-month-ahead exchange rate forecasts with Taylor rule fundamentals and Taylor rule differentials. For the purpose of comparison, we also evaluate the out-of-sample performance of the interest rate differentials, monetary, and PPP models. We use data over the period March 1973 – February 1983 for estimation and reserve the remaining data for out-of-sample forecasting exercise. To evaluate the out-of-sample performance of the models, we estimate them by OLS in rolling regressions with a 120-month window, construct 381 forecasts, and calculate the CW statistics to tests for equal predictive ability between the driftless random walk and the alternative linear model.

4.3 Taylor Rule Fundamentals

We estimate 20 specifications of the Taylor rule fundamentals model with a constant, with heterogeneous or homogenous coefficients on inflation and the output gap for the U.S. and the foreign country, and with or without the real exchange rate. Table 1 reports the results for 1-month-ahead forecasts of exchange rates using symmetric Taylor rule fundamentals with homogenous (Panel A) and heterogeneous coefficients (Panel B). For each class of models, we estimate five specifications of the Taylor rule fundamentals model. Column 1 of Table 1 reports the CW statistics for the model with no smoothing. Columns 2 and 4 include lagged interest rates differential in addition to the U.S. and foreign inflation and output gaps, and Columns 3 and 5 include individual lagged interest rates. Columns 2 and 3 use money market rates and Columns 4 and 5 replace the FFR with the Wu and Xia (2014) shadow FFR for the U.S.

Panel A of Table 1 reports the results for symmetric Taylor rule fundamentals model with homogenous coefficients. The model significantly outperforms the random walk for 4 out of 8 countries with no smoothing (Canada and Germany at the 5 percent significance level and Japan and Switzerland at the 10 percent level), for the same 4 countries when the lagged money market rate differential is included (Canada and Japan at the 1 percent, Switzerland at the 5 percent, and

[7] Wu and Xia (2014) shadow rate can be accessed at https://www.frbatlanta.org/cqer/researchcq/shadow_rate.aspx.

Germany at the 10 percent level), and when the lagged shadow federal funds rate is used in differential form (Canada at the 1 percent and Germany, Japan and Switzerland at the 5 percent level). The evidence of predictability is stronger with individual lagged interest rates. The models with Taylor rule fundamentals outperform the random walk for 5 countries with individual money market rates (Canada and Japan at the 1 percent level and Australia, Germany and Switzerland at the 5 percent level) and for 6 countries with shadow federal funds rate for the U.S. (Canada, Germany, and Japan at the 1 percent, Australia at the 5 percent, and Switzerland and the U.K at the 10 percent level). Overall, the model outperforms the random walk for 6 out of 8 countries with at least one specification.

Panel B of Table 1 reports the results for symmetric Taylor rule fundamentals model with heterogeneous coefficients. The model with no smoothing significantly outperforms the random walk for 7 out of 8 countries (Australia, Canada, Sweden, and the U.K. at the 1 percent, Switzerland and Germany at the 5 percent, and Denmark at the 10 percent significance level). When smoothing is introduced using interest rate differential, the model significantly outperforms the random walk 7 countries with money market rate (Australia, Canada, Sweden, and the U.K. at the 1 percent, Japan and Switzerland at the 5 percent, and Germany at the 10 percent level) and for all 8 countries with shadow federal funds rate for the U.S. (Australia, Canada, Sweden, and the U.K. at the 1 percent, Germany at the 5 percent, and Denmark, Japan, and Switzerland at the 10 percent level). The model with individual lagged interest rates significantly outperforms the random walk for all 8 countries with money market rate (Australia, Canada, Japan, Sweden, and the U.K. at the 1 percent, Germany and Switzerland at the 5 percent, and Denmark at the 10 percent level) and for 7 countries with shadow federal funds rate (Australia, Canada, Sweden, Japan, and the U.K. at the 1 percent and Germany and Switzerland at the 5 percent level). Overall, the symmetric Taylor rule fundamentals model with heterogeneous coefficients outperforms the random walk for all 8 countries with at least three specifications. This model was also found to be the best-performing model in Molodtsova and Papell (2009), where significant evidence of exchange rate predictability was found for 9 out of 12 countries.

Table 2 shows the results for asymmetric Taylor rule fundamentals models that incorporate the real exchange rate. Compared to the results in Table 1, the evidence of predictability is weaker for the asymmetric than for the symmetric Taylor rule fundamentals models. The asymmetric model with homogenous coefficients significantly outperforms the random walk for 3 countries with no smoothing (Canada at the 5 percent and Germany and Japan at the 10 percent level) and for 2 countries when either the lagged money market rate or the shadow federal funds rate differential is included (Canada and Japan at the 1 percent level). The evidence of predictability is slightly stronger with individual lagged interest rates. The asymmetric model with Taylor rule fundamentals outperforms the random walk without drift for 5 countries with individual lagged money market rates (Australia, Canada and Japan at the 1 percent, Sweden at the 5 percent, and Germany at the 10 percent level) and with individual lagged shadow federal funds rates (Australia and Canada at the 1 percent and Germany, Japan, and Sweden at the 5 percent level). Overall, the model outperforms the random walk without drift for 5 out of 8 countries with at least two specifications.

The evidence of predictability is again stronger with heterogeneous coefficients. Panel B of Table 2 reports the results for asymmetric Taylor rule fundamentals model with heterogeneous coefficients. The model with no smoothing significantly outperforms the random walk for 6 countries (Australia, Canada, Sweden, and the U.K. at the 1 percent and Switzerland and Germany at the 10 percent level). When smoothing is introduced using the lagged interest rate differential, the model significantly outperforms the random walk for 5 countries with the money market rate (Australia, Canada, and the U.K. at the 1 percent, Japan at the 5 percent, and Switzerland at the 10 percent level) and for 4 out of 8 countries with shadow federal funds rate for the U.S. (Australia, Canada, and the U.K. at the 1 percent, and Japan at the 10 percent level). The model with individual lagged interest rates significantly outperforms the random walk for the same 6 countries with money market rate and with shadow federal funds rate (Australia, Canada, and the U.K. at the 1 percent, Japan and Sweden at the 5 percent, and Switzerland at the 10 percent level). Overall, the model outperforms the random walk for 7 out of 8 countries with at least one specification.

4.4 Taylor Rule Differentials

We estimate 15 specifications for three Taylor rule differentials models described in Section 2, the original Taylor (1993) rule, the modified Taylor rule with a higher output gap coefficient, and a hybrid Taylor rule with a higher output gap coefficient for the U.S. but not for the foreign country, for each of the five specifications described above. Table 3 depicts the results for 1-month-ahead forecasts of exchange rates using symmetric Taylor rule differentials models.[8] The best-performing model is the hybrid Taylor rule model (Panel C), for which the random walk null is rejected for 5 out of 8 countries with at least one specification. For the hybrid Taylor rule differentials model with no smoothing, the no predictability null can be rejected for 4 countries (Australia, Canada, Germany, and Japan at the 10 percent significance level). When smoothing is introduced, the evidence of predictability is somewhat stronger, especially when the shadow federal funds rate is used. The hybrid Taylor rule differentials model significantly outperforms the random walk 4 countries with the lagged money market rate differential and with the shadow federal funds rate differential (Japan at the 1 percent, Canada at the 5 percent, and Australia and Switzerland at the 10 percent level). The model outperforms the random walk for 4 countries with individual lagged money market rates (Japan at the 1 percent, Australia and Canada at the 5 percent, and Switzerland at the 10 percent level) and for 5 countries with individual lagged shadow federal funds rates (Japan at the 1 percent, Australia and Canada at the 5 percent, and Germany and Switzerland at the 10 percent level).

The other two Taylor rule models significantly outperform the random walk for 4 out of 8 countries with a least 2 specifications. For the original Taylor rule differentials model with no smoothing, the no predictability null can be rejected for 3 countries (Canada at the 5 percent and Japan and Sweden at the 10 percent level). The original Taylor rule differentials model significantly outperforms the random walk for 2 countries with a lagged interest rate differential (Australia and Japan at the 1 percent level). When smoothing is introduced using individual lagged interest rates, the evidence of predictability is slightly stronger. The original Taylor rule differentials model outperforms the random walk for 4 countries with individual lagged money market rates (Canada and Japan at the 1 percent, Australia at the 5 percent, and Sweden at the 10 percent significance level) and with individual lagged shadow federal funds rates (Canada and Japan at the 1 percent and Australia and Sweden at the 5 percent level).

For the modified Taylor rule differentials model with no smoothing, the no predictability null can be rejected for 2 of the 8 countries (Japan at the 5 percent and Canada at the 10 percent level). The modified Taylor rule differentials model significantly outperforms the random walk for 3 out of 8 countries with a lagged money market rate differential (Canada and Japan at the 1 percent and Switzerland at the 10 percent level) and with a lagged shadow federal funds rate for

[8] The results for asymmetric specifications that introduce the real exchange rate with a coefficient of 0.1, as in Engel, Mark, and West (2008), produce similar results.

the U.S. (Japan at the 1 percent, Canada at the 5 percent, and Switzerland at the 10 percent level). When smoothing is introduced using individual interest rates, the evidence of predictability is slightly stronger. The original Taylor rule differentials model outperforms the random walk for 4 countries (Japan at the 1 percent, Australia and Canada at the 5 percent, and Switzerland at the 10 percent level).

4.5 Interest Rate, PPP, and Monetary Fundamentals

Table 4 contains the results for one-month-ahead forecasts of exchange rates using the interest rate, PPP, and monetary models described in Section 2. The evidence of predictability is much weaker with the conventional models. The strongest evidence of predictability is found with interest rate models, where the model outperforms the random walk for 2 out of 8 countries when the money market rate is used (Japan at the 1 percent and Switzerland at the 5 percent level) and for 3 countries when shadow federal funds rate is used (Japan and Switzerland at the 5 percent level and Canada at the 10 percent level). The evidence of predictability is even weaker for the monetary models. With the coefficient on relative output k equal to 0, the no predictability null can be rejected for 2 out of 8 countries (Switzerland at the 5 percent, and Japan at the 10 percent level). With $k=1$, the evidence of predictability is found only for Switzerland at the 5 percent significance level. No evidence of one-month-ahead predictability is found with the PPP model.

5. Taylor Rules and Taylor Rule Predictability

We have presented evidence that the Taylor rule fundamentals model of Molodtsova and Papell (2009) continues to provide evidence of out-of-sample exchange rate predictability when the data is extended to include the financial crisis, the Great Recession, and the zero lower bound on the federal funds rate. The Taylor rule fundamentals model provides more evidence of predictability than the Taylor rule differentials model of Engel and West (2008), and much more evidence of predictability than the traditional interest rate, Purchasing Power Parity, and monetary models.

Since the Taylor rule fundamentals model uses data on the variables that enter Taylor rules, inflation rates, output gaps, and (depending on the specification) the real exchange rate and/or lagged interest rates, but does not use coefficients from either postulated or estimated Taylor rules, it leaves open the question of whether finding evidence of out-of-sample exchange rate predictability with the Taylor rule fundamentals model is related to central banks following the Taylor rule.

What does it mean for a central bank to follow a Taylor rule? Nikolsko-Rzhevskyy, Papell, and Prodan (2014) estimate Bai and Perron (1998) tests for multiple structural breaks on Taylor rule deviations, the absolute value of the difference between the federal funds rate and the rate prescribed by the original Taylor rule, for the U.S. using real-time data from 1965:4 to 2013:4, and identify periods of high and low deviations. The output gap is the percentage deviation of GDP/GNP from a quadratic trend, and inflation is the percentage change in the GDP/GNP deflator.[9] The Federal funds rate is used for the policy rate until 2008:Q4 and the shadow Federal funds rate of Wu and Xia (2014) thereafter. The tests identify significant breaks in 1974:Q3, 1985:Q1, and 2000:Q4, producing low deviations eras from 1965:Q4 – 1974:Q3 and 1985:Q2 – 2000:Q4 and high deviations eras from 1974:Q4 – 1985:Q1 and 2001:Q1 – 2013:Q4.[10]

Table 5 reports CW statistics for the Taylor rule fundamentals model when the data is divided into periods based on low and high original Taylor rule deviations for the U.S. We report statistics for the symmetric model with heterogeneous coefficients, which provided the strongest full-sample evidence of predictability. Because our first forecast is in March 1983 and there is a break in 1985:Q1, we call 1985:M4 – 2000:M12 a low deviations period and 2001:M1 – 2014:M12 a high deviations period. The results do not support the hypothesis that out-of-sample exchange rate predictability with Taylor rule fundamentals is more successful during periods with closer adherence to the original Taylor rule. Switzerland is the only country for which the evidence of exchange rate predictability is stronger during periods of low Taylor rule deviations. For Australia, Denmark, Germany, and Sweden, the evidence of predictability is stronger during the period of high Taylor rule deviations and, for Canada, Japan, and the United Kingdom, the evidence of predictability is about the same in the high and low deviations periods.[11]

Nikolsko-Rzhevskyy, Papell, and Prodan (2014) also calculate deviations from a modified Taylor rule with an output gap coefficient of 1.0 instead of 0.5. The tests identify

[9] The data is from the Real-Time Data Set for Macroeconomists, originated by Croushore and Stark (2001). Nikolsko-Rzhevskyy, Papell, and Prodan (2014) show that real-time quadratic detrending corresponds much more closely to U.S. recessions and expansions than real-time linear or Hodrick-Prescott detrending.

[10] The breaks and eras are the same if the data is extended to 2014:Q4.

[11] Since we do not know of a test to formally compare the CW statistic across the same model and different time periods, the statements of “stronger” and “weaker” evidence are based on visual examination of the results.

significant breaks in 1977:Q4, 1984:Q4, and 1999:Q1, and 2006:Q3, producing low deviations eras from 1965:Q4 – 1977:Q4, 1985:Q1 – 1999:Q1, and 2006:Q4 – 2013:Q4 and high deviations eras from 1978:Q1 – 1984:Q4 and 1999:Q2 – 2006:Q3. Within the period covered by our forecasts, this produces low deviations eras from 1985:M1 – 1999:M3 and 2006:M10 – 2014:M12 and a high deviations era from 1999:M4 – 2006:M9.

Table 6 reports CW statistics for the Taylor rule fundamentals model when the data is divided into periods based on low and high modified Taylor rule deviations for the U.S. Table 6A reports the CW statistics for the three sub-periods and Table 6B combines the two low deviations periods into one era. The results strongly support the hypothesis that out-of-sample exchange rate predictability with Taylor rule fundamentals is more successful during periods with closer adherence to the modified Taylor rule. The results are clearest in Table 6B. For Australia, Canada, Germany, Japan, Sweden, Switzerland, and the United Kingdom, the evidence of predictability is stronger during the periods of low Taylor rule deviations than during the period of high Taylor rule deviations for virtually every model.[12] For Denmark, there is weak (10 percent) evidence of predictability during the 2006:M10 – 2014:M12 low deviations period across all models that disappears when it is combined with the 1985:M1 – 1999:M3 low deviations period.[13]

The result that evidence of out-of-sample exchange rate predictability is stronger during periods of low deviations than during periods of high deviations for the modified, but not the original, Taylor rule is based on deviations calculated for the U.S. Teryoshin (2014), using real-time data from Fernandez, Koenig, and Nikolsko-Rzhevskyy (2011), uses Bai and Perron (1998) to identify periods of high and low deviations from both the original and modified Taylor rule for 10 additional countries, including six countries, Australia, Canada, Japan, Sweden, Switzerland, and the United Kingdom, studied in this paper. We use his country-by-country results to investigate whether the results obtained using U.S. data extend to other countries' data.

The results for the original Taylor rule are reported in Table 7. The dates of the high and low deviations eras are different country-by-country and, unlike for the U.S., there are also some intermediate eras. The results do not support the hypothesis that out-of-sample exchange rate predictability with Taylor rule fundamentals is more successful during periods with closer

[12] The only exception among the 35 cases (7 countries times 5 models) is for the no smoothing model for Japan.
[13] The exception to this statement is that, for the specification with smoothing, lagged interest rate differentials, and the shadow federal funds rate, the rejection is at the 5 percent level for the 2006:M10 – 2014:M12 period.

adherence to the original Taylor rule. Japan is the only country for which the evidence of exchange rate predictability is stronger during periods of low and intermediate Taylor rule deviations and Australia is the only country for which the evidence of predictability is stronger during periods of high deviations. The evidence is mixed for Canada, Sweden, and the United Kingdom, and there are no significant structural breaks, and therefore no distinct eras, for Switzerland.

The results for the modified Taylor rule are reported in Table 8. The results do not support the hypothesis that out-of-sample exchange rate predictability with Taylor rule fundamentals is more successful during periods with closer adherence to the modified Taylor rule. Switzerland is the only country for which the evidence of exchange rate predictability is stronger during periods of low and intermediate Taylor rule deviations and Japan is the only country for which the evidence of predictability is stronger during periods of high deviations. The evidence is mixed for Australia, Canada, Sweden, and the United Kingdom.

Monetary policy evaluation with Taylor rules is typically conducted in terms of the Taylor principle that the nominal interest rate is raised more than point-for-point when inflation increases. This is both necessary and sufficient for stationarity of inflation in a textbook IS curve, Phillips curve, and Taylor rule model and necessary and almost sufficient for determinacy of inflation in the forward-looking IS curve, New Keynesian Phillips curve, and Taylor rule model of Woodford (2003). Nikolsko-Rzhevskyy, Papell, and Prodan (2015) identify low, positive, and negative deviations eras from the original and modified Taylor rule by conducting structural change tests on the difference between the actual and prescribed federal funds rate. They use the difference, rather than the absolute value of the difference, between the rates in order to estimate Taylor rules over the sub-periods defined by the tests. For the period covered by our out-of-sample exchange rate forecasting, the Taylor principle holds during 1983:M3 – 1999:M3 because the coefficient on inflation is significantly greater than one, the evidence is mixed between 1999:M4 – 2007:M6 because, while the coefficient on inflation is greater than one, it is not significantly greater than one, and the Taylor principle does not hold for 2007:M7 – 2014:M12 because the coefficient on inflation is less than one.

Table 9 reports CW statistics for the Taylor rule fundamentals model when the data is divided into periods based on adherence to the Taylor principle for the U.S. Out-of-sample exchange rate predictability with Taylor rule fundamentals is not more successful during periods with closer adherence to the Taylor principle. Switzerland is the only country for which the evidence of exchange rate predictability is stronger during periods of stronger adherence to the Taylor principle. For Australia, Denmark, Germany, and Sweden, the evidence of predictability is stronger during the periods of less adherence and, for Canada, Japan, and the United Kingdom, the evidence of predictability is about the same in the high and low adherence periods. This pattern exactly matches the results for the original Taylor rule because the period where the Taylor principle holds closely overlaps the low deviations era and the periods where the evidence is mixed and where the Taylor principle does not hold closely overlap the high deviations era. The pattern is very different from the results with the modified Taylor rule because the overlap is much lower.

6. Conclusion

The Taylor rule fundamentals model of Molodtsova and Papell (2009) was motivated by the shift in policy evaluation over the past twenty-five years from money supplies to interest rates as the instrument of monetary policy. Using data from the start of the post-Bretton Woods floating exchange rate era in 1973 through the end of 2014, the model provides evidence of out-of-sample exchange rate predictability for all of the eight countries in our sample. The Taylor rule fundamentals model provides stronger evidence of predictability than the Taylor rule differentials model of Engel, Mark, and West (2008) and much stronger evidence of predictability than the traditional interest rate, Purchasing Power Parity, and monetary models.

The most successful specifications allow for heterogeneous coefficients on domestic and foreign inflation and output gaps, but do not include the real exchange rate. These were also the most successful specifications in Molodtsova and Papell (2009) using data from 1983 through mid-2006, and demonstrate that out-of-sample exchange rate predictability with Taylor rule fundamentals has survived the financial crisis, the Great Recession, and the zero lower bound on the federal funds rate

Because the Taylor rule fundamentals model uses the variables included in the Taylor rule, U.S. and foreign inflation, output gaps, and (depending on the specification) lagged interest rates and/or the real exchange rate, but does not impose either postulated or estimated coefficients on the variables, finding evidence of out-of-sample exchange rate predictability does not, by itself, provide a link between the Taylor rule and the findings of predictability. In order to investigate whether there is a link between adherence to the Taylor rule and out-of-sample exchange rate predictability, we utilize the Taylor rule deviations calculated by Nikolsko-Rzhevskyy, Papell, and Prodan (2014), who use tests for multiple structural changes to identify periods of low and high deviations from both the original Taylor rule, with the coefficients as in Taylor (1993), and the modified Taylor rule, with a higher coefficient on the output gap as in Yellen (2012).

The results with the modified Taylor rule strongly support the hypothesis that out-of-sample exchange rate predictability with Taylor rule fundamentals is more successful during periods with closer adherence to the modified Taylor rule, as the evidence of predictability is stronger during the periods of low Taylor rule deviations than during the period of high Taylor rule deviations for seven of the eight countries. The evidence of predictability is not, however, stronger when periods of high and low deviations are calculated from the original Taylor rule, calculated from Taylor rules for the foreign countries, or divided according by adherence to the Taylor principle.

The Taylor rule fundamentals model provides stronger evidence of out-of-sample exchange rate predictability than the Taylor rule differentials model, and much stronger evidence than traditional models. Using the modified Taylor rule, which doubles the output gap coefficient in the original Taylor rule and has been identified with Fed policy as articulated by Yellen (2012), we divide the period between 1983 and 2014 into low and high deviations eras. Out-of-sample exchange rate predictability with Taylor rule fundamentals model is much stronger in low deviations eras than in high deviations eras.

References

Bacchetta, Philippe and Eric van Wincoop, "Infrequent Portfolio Decisions: A Solution to the Forward Discount Puzzle" *American Economic Review* 100, 2010, pp. 870-904

Bai, Jushan and Pierre Perron, "Estimating and Testing Linear Models with Multiple Structural Changes" *Econometrica* 66, 1998, pp.47–78

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 24*, 2005, 1150-1175.

Chinn, Menzie, "ZIRP and the exchange rate...and other macro variables" [Weblog Entry], Econbrowser, 22 December 2008, http://www.econbrowser.com/archives/2008/12/zirp_and_the_ex.html, 22 December 2008

__________,"The (Partial) Rehabilitation of Interest Rate Parity in the Floating Rate Era: Longer Horizons, Alternative Expectations, and Emerging Markets" *Journal of International Money and Finance* 26, 2006, pp. 7-21

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

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

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

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

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, 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, 2008, pp. 381-441

Engel, Charles, Nelson C. Mark, and Kenneth D. West, "Factor Model Forecasts of Exchange Rates" *Econometric Reviews* 34(1/2), 2015, pp. 32-55

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

Fernandez, Adriana, Evan F. Koenig and Alex Nikolsko-Rzhevskyy, "The Real-Time Historical Database for the OECD" 2011, Federal Reserve Bank of Dallas, Globalization and Monetary Policy Institute Working Paper No. 96

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

Ince, Onur, "Forecasting Exchange Rates Out-of-Sample with Panel Methods and Real-Time Data" *Journal of International Money and Finance 43*, 2014, pp.1-18

Ince, Onur and David Papell, "The (Un)Reliability of Real-Time Output Gap Estimates with Revised Data", *Economic Modelling 33*, 2013, pp. 713-721

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

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

McCracken, Michael, “Asymptotics for Out-of-Sample Tests of Granger Causality” *Journal of Econometrics 140*, 2007, pp.719-752

Molodtsova, Tanya and David H. Papell, “Exchange Rate Predictability with Taylor Rule Fundamentals” *Journal of International Economics 77*, 2009, pp. 167-180

__________, “Taylor Rule Exchange Rate Forecasting during the Financial Crisis” *NBER Working Paper* #18330, *NBER International Seminar on Macroeconomics 2012*, Volume 9, Francesco Giavazzi and Kenneth D. West, eds., University of Chicago Press, 2013, pp. 55-97

Molodtsova, Tanya, Alex Nikolsko-Rzhevskyy and David H. Papell, “Taylor Rules with Real-Time Data: A Tale of Two Countries and One Exchange Rate” *Journal of Monetary Economics 55*, 2008, pp. S63-S79

__________, “Taylor Rules and the Euro” *Journal of Money, Credit, and Banking*, 2011, pp. 535-552

Nikolsko-Rzhevskyy, Alex, David Papell and Ruxandra Prodan, “Deviations from Rules-Based Policy and Their Effects” *Journal of Economic Dynamics and Control 49, 2014, pp. 4-17*

__________, “The Taylor Principles”, manuscript, 2015, Lehigh University and University of Houston

Orphanides, Athanasios and Simon van Norden, “The Unreliability of Output Gap Estimates in Real Time” *Review of Economics and Statistics* 84, 2002, pp. 569-583

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

Rossi, Barbara, “Exchange Rate Predictability” *Journal of Economic Literature* 51(4), 2013, pp.1063-1119

Rudebusch, Glenn, “The Fed’s Exit Strategy for Monetary Policy” *Federal Reserve Bank of San Francisco Economic Letter* 18, June 14, 2010, pp. 1-5

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, pp.1-14

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

Teryoshin, Yevgeniy, “Historical Performance of Discretionary and Rule-Based Monetary Policy” unpublished, 2014, Stanford University

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

Woodford, Michael, “Interest and Prices” 2003, Princeton University Press

Wu, Jing Cynthia and Fan Dora Xia “Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound” *National Bureau of Economic Research* Working Paper 20117,

Yellen, Janet, “Perspectives on Monetary Policy” speech at the Boston Economic Club Dinner, June 6, 2012

Table 1. Symmetric Taylor Rule Fundamentals Model

Country	No Smoothing	Smoothing Differential FFR	Smoothing Individual FFR	Smoothing Differential Shadow FFR	Smoothing Individual Shadow FFR
			A. Homogenous Coefficients		
Australia	0.055	0.344	1.874**	0.510	1.894**
Canada	2.427***	3.544***	3.126***	3.518***	3.167***
Denmark	-0.516	0.022	0.576	0.469	0.982
Germany	2.173**	1.341*	2.172**	2.106**	2.652***
Japan	1.611*	2.591***	2.440***	2.252**	2.391***
Sweden	1.217	-0.385	0.799	-0.210	0.982
Switzerland	1.554*	1.795**	1.716**	1.684**	1.612*
U.K.	0.342	0.322	1.097	0.800	1.409*
			B. Heterogeneous Coefficients		
Australia	3.250***	3.281***	3.213***	3.166***	3.051***
Canada	2.892***	3.627***	3.610***	3.294***	3.293***
Denmark	1.349*	1.233	1.321*	1.299*	0.928
Germany	2.152**	1.423*	2.120**	1.809**	2.251**
Japan	0.392	2.308**	2.492***	1.631*	2.353***
Sweden	3.968***	3.236***	2.906***	3.381***	2.944***
Switzerland	1.878**	1.733**	1.991**	1.501*	1.659**
U.K.	2.384***	2.834***	3.071***	3.106***	3.200***

Notes to Tables 1-3: The tables reports CW statistics for the 1-month-ahead tests of equal predictive ability between the null of a driftless random walk and the alternative of a linear model with Taylor rule fundamentals (Tables 1 and 2) and Taylor rule differentials (Table 3). In Table 1, the alternative model is the model with symmetric Taylor rule fundamentals with and without smoothing, which is estimated with heterogeneous and homogenous inflation and output coefficients using quadratic trend to estimate potential output. The column "Smoothing Differential" reports the results of estimating the same Taylor rule fundamentals model with smoothing as in Molodtsova and Papell (2009), where lagged interest rate differential is used on the right-hand side. The column "Smoothing Individual" reports the results of estimating the Taylor Rule fundamentals model with smoothing, where individual lagged interest rates are used on the right-hand-side. The models with smoothing in the last two columns use FFR until 2008:M12 and Wu and Xia (2014) shadow market interest rate after 2009:M1for the U.S. *, **, and *** indicate that the alternative model significantly outperforms the random walk at 10, 5, and 1% significance level, respectively, based on standard normal critical values for the one-sided test. Rolling regressions with 120-month window are used to predict exchange rate changes from 1983:M3 to 2014:M12. The models are estimated using data from January 1975 for Canada and Denmark, September 1975 for Switzerland, and from March 1973 for the rest of the countries. For the models with smoothing, the sample ends in June 2012 for Germany due to unavailability of interest rate data. The sample ends in December 2014 for the rest of the countries. The results for Germany are calculated using synthetic Deutschmark/Dollar rate after 2009:M1 as in Engel, Mark, and West (2008) and German inflation and quadratic output gap.

Table 2. Asymmetric Taylor Rule Fundamentals Model

Country	No Smoothing	Smoothing Differential FFR	Smoothing Individual FFR	Smoothing Differential Shadow FFR	Smoothing Individual Shadow FFR
			A. Homogenous Coefficients		
Australia	-0.157	0.337	2.749***	0.350	2.622***
Canada	2.209**	3.051***	2.898***	3.045***	3.014***
Denmark	-0.947	-0.149	-0.065	0.282	0.276
Germany	1.451*	0.231	1.410*	1.126	1.836**
Japan	1.447*	2.679***	2.249***	2.361***	2.081**
Sweden	0.956	-0.420	1.664**	-0.249	1.952**
Switzerland	-0.080	0.868	0.817	0.925	0.896
U.K.	0.540	0.047	0.626	0.608	1.112
			B. Heterogeneous Coefficients		
Australia	3.431***	3.435***	3.534***	3.252***	3.246***
Canada	2.629***	2.979***	3.048***	2.757***	2.851***
Denmark	0.823	0.783	0.623	0.792	0.153
Germany	1.331*	0.240	0.674	0.713	0.760
Japan	0.835	2.216**	1.993**	1.642*	1.816**
Sweden	2.500***	0.726	1.682**	0.616	1.745**
Switzerland	1.384*	1.445*	1.613*	1.175	1.395*
U.K.	2.517***	3.088***	3.017***	3.311***	3.217***

Table 3. Symmetric Taylor Rule Differentials Models

Country	No Smoothing	Smoothing Differential FFR	Smoothing Individual FFR	Smoothing Differential Shadow FFR	Smoothing Individual Shadow FFR
			A. Original Taylor Rule Model		
Australia	0.998	0.659	2.150**	1.019	2.204**
Canada	2.135**	3.233***	2.666***	2.858***	2.592***
Denmark	-0.821	-0.448	0.289	-0.149	0.497
Germany	0.939	0.017	0.661	0.628	1.166
Japan	1.463*	2.969***	2.665***	2.727***	2.595***
Sweden	1.583*	0.720	1.586*	0.933	1.707**
Switzerland	0.968	1.253	1.251	1.208	1.234
U.K.	-0.375	-0.071	0.499	0.395	0.839
			B. Modified Taylor Rule Model		
Australia	0.589	0.435	1.963**	0.787	2.051**
Canada	1.463*	2.637***	2.225**	2.313**	2.204**
Denmark	-1.083	-0.866	0.053	-0.576	0.245
Germany	0.071	-0.056	0.778	0.577	1.134
Japan	1.910**	3.261***	3.267***	2.972***	3.221***
Sweden	0.921	-0.547	0.673	-0.315	0.758
Switzerland	0.638	1.330*	1.300*	1.318*	1.299*
U.K.	-0.607	-0.262	0.503	0.195	0.834
			C. Hybrid Taylor Rule Model		
Australia	1.334*	1.385*	2.161**	1.606*	2.215**
Canada	1.287*	2.142**	1.865**	2.098**	2.046**
Denmark	-0.061	0.160	0.293	0.363	0.372
Germany	1.281*	0.390	0.856	0.918	1.346*
Japan	1.592*	3.484***	3.375***	3.152***	3.149***
Sweden	0.714	-0.734	-0.565	-0.648	-0.502
Switzerland	1.183	1.366*	1.340*	1.325*	1.358*
U.K.	-1.744	-0.553	0.305	-0.061	0.701

Notes: The table reports the CW statistics for the tests of equal predictability between the linear model with Taylor rule differentials and random walk without drift. The Table contains the results for the original Taylor rule differentials model with coefficients of 1.5 on inflation and 0.5 on the output gap for both countries (Panel A), modified Taylor rule differentials model with coefficients of 1.5 on inflation and 1.0 on the output gap for both countries (Panel B), and hybrid Taylor rule differentials model with coefficients of 1.5 on inflation in both countries, 1.0 on U.S. output gap, and 0.5 on foreign output gap (Panel C). *, **, and *** denote test statistics significant at 10, 5, and 1% level, respectively, based on standard normal critical values for the CW statistic. Also, see notes to Table 1.

Table 4. Models with Interest Rates, PPP, and Monetary Fundamentals

Country	Interest Rates FFR	Interest Rates Shadow FFR	PPP	Monetary (k=0)	Monetary (k=1)
Australia	0.481	0.671	-0.994	-0.311	-0.059
Canada	1.179	1.386*	-0.492	1.139	-0.262
Denmark	-0.931	-0.808	-1.097	-1.143	-0.756
Germany	0.391	0.163	-0.848	-0.316	-0.280
Japan	2.579***	2.030**	0.855	1.554*	0.186
Sweden	-1.494	-1.212	-0.721	-0.587	0.125
Switzerland	2.102**	1.845**	-1.066	1.973**	1.892**
U.K.	0.376	0.544	0.227	-0.010	0.240

Notes: The table reports CW statistics for 1-month-ahead tests of equal predictive ability between the null of a driftless random walk and the alternative of a linear model. The alternative models are the model with interest rates, PPP, and monetary fundamentals. The model with interest rates in the first two columns use money market rate (Column 1) and FFR until 2008:M12 and Wu and Xia (2014) shadow market interest rate after 2009:M1for the U.S. (Column 2) The monetary fundamentals are estimated with a value of the income elasticity, k, set either to 0 or 1. *, **, and *** indicate that the alternative model significantly outperforms the random walk at 10, 5, and 1% significance level, respectively, based on standard normal critical values for the one-sided test. The interest rates models are estimated using data from January 1975 for Canada, September 1975 for Switzerland, and March 1973 for the rest of the countries. The PPP and monetary models are estimated using data from March 1973 for all of the countries. For the interest rate models, the sample ends in June 2012 for Germany due to unavailability of interest rate data. The sample ends in December 2014 for all other countries and models. The models for Germany are estimated using synthetic Deutschmark/Dollar rate after 2009:M1 as in EMW (2007).

Table 5. CW Statistics for Taylor Rule Fundamentals Models:

Deviations from Original Taylor Rule for the U.S.

Country		Deviations	No Smoothing	Smoothing Differential FFR	Smoothing Individual FFR	Smoothing Differential Shadow FFR	Smoothing Individual Shadow FFR
Australia	1985:M4-2000:M12	Low	0.602	0.656	0.919	0.561	0.857
	2001:M1-2014:M12	High	3.387^{***}	3.367^{***}	3.063^{***}	3.273^{***}	2.900^{***}
Canada	1985:M4-2000:M12	Low	1.180	2.451^{***}	2.554^{***}	1.780^{**}	1.867^{**}
	2001:M1-2014:M12	High	2.581^{***}	2.909^{***}	2.939^{***}	2.831^{***}	2.827^{***}
Denmark	1985:M4-2000:M12	Low	-0.020	-0.124	0.192	-0.149	-0.286
	2001:M1-2014:M12	High	1.846^{**}	1.906^{**}	1.655^{**}	2.070^{**}	1.662^{*}
Germany	1985:M4-2000:M12	Low	-0.285	-0.180	0.945	0.325	1.092
	2001:M1-2014:M12	High	2.787^{***}	2.449^{***}	2.167^{**}	2.430^{***}	2.220^{**}
Japan	1985:M4-2000:M12	Low	-0.353	1.735^{**}	2.099^{**}	0.832	1.921^{**}
	2001:M1-2014:M12	High	1.498^{*}	1.990^{**}	1.812^{**}	1.963^{**}	1.797^{**}
Sweden	1985:M4-2000:M12	Low	0.351	-0.757	-1.275	-0.627	-1.282
	2001:M1-2014:M12	High	4.052^{***}	3.782^{***}	3.306^{***}	3.872^{***}	3.326^{***}
Switzerland	1985:M4-2000:M12	Low	1.097	1.333^{*}	1.912^{**}	1.149	1.680^{**}
	2001:M1-2014:M12	High	1.759^{**}	1.135	0.671	0.992	0.413
U.K.	1985:M4-2000:M12	Low	1.175	1.501^{*}	1.670^{**}	1.680^{**}	1.820^{**}
	2001:M1-2014:M12	High	1.911^{**}	1.817^{**}	1.999^{**}	2.085^{**}	2.152^{**}

Table 6A. CW Statistics for Taylor Rule Fundamentals Models:

Deviations from Modified Taylor Rule for the U.S.

Country		Deviations	No Smoothing	Smoothing Differential FFR	Smoothing Individual FFR	Smoothing Differential Shadow FFR	Smoothing Individual Shadow FFR
Australia	1985:M1-1999:M3	Low	1.141	1.288*	1.503*	1.165	1.572*
	1999:M4-2006:M9	High	1.254	1.501*	1.776**	1.409*	1.140
	2006:M10-2014:M12	Low	3.074***	2.921***	2.466***	2.894***	2.520***
Canada	1985:M1-1999:M3	Low	1.797**	2.784***	2.796***	2.160**	2.202**
	1999:M4-2006:M9	High	1.473*	1.485*	1.591*	1.360*	1.268
	2006:M10-2014:M12	Low	2.083**	2.499***	2.513***	2.466***	2.512***
Denmark	1985:M1-1999:M3	Low	0.254	0.215	0.332	0.233	0.015
	1999:M4-2006:M9	High	0.822	0.411	0.523	0.281	-0.081
	2006:M10-2014:M12	Low	1.414*	1.564*	1.482*	1.753**	1.544*
Germany	1985:M1-1999:M3	Low	0.052	-0.062	0.751	0.657	1.116
	1999:M4-2006:M9	High	0.581	0.431	1.099	0.264	0.876
	2006:M10-2014:M12	Low	2.801***	2.643***	2.326***	2.604***	2.193**
Japan	1985:M1-1999:M3	Low	-0.241	1.753**	2.712***	1.029	2.590***
	1999:M4-2006:M9	High	-0.289	0.959	0.113	0.507	-0.129
	2006:M10-2014:M12	Low	1.590*	1.747**	1.506*	1.731**	1.541*
Sweden	1985:M1-1999:M3	Low	0.128	-0.755	-1.143	-0.656	-1.274
	1999:M4-2006:M9	High	1.814**	1.445*	1.182	1.519*	1.273
	2006:M10-2014:M12	Low	3.785***	3.691***	3.185***	3.731***	3.196***
Switzerland	1985:M1-1999:M3	Low	1.210	1.532*	1.729**	1.392*	1.596*
	1999:M4-2006:M9	High	1.141	0.198	0.360	-0.086	-0.124
	2006:M10-2014:M12	Low	1.134	0.861	1.034	0.775	0.883
U.K.	1985:M1-1999:M3	Low	1.138	1.481*	1.538*	1.625*	1.703**
	1999:M4-2006:M9	High	0.748	0.478	1.060	0.779	1.005
	2006:M10-2014:M12	Low	2.082***	1.986**	2.031**	2.197**	2.173**

Table 6B. CW Statistics for Taylor Rule Fundamentals Models:

Deviations from Modified Taylor Rule for the U.S.

Country	Deviations	No Smoothing	Smoothing Differential FFR	Smoothing Individual FFR	Smoothing Differential Shadow FFR	Smoothing Individual Shadow FFR
Australia						
85:M1-99M3 & 06:M10-14M12	Low	3.171***	3.103***	2.863***	3.017***	2.943***
99:M4-06:M9	High	1.254	1.501*	1.776**	1.409*	1.140
Canada						
85:M1-99M3 & 06:M10-14M12	Low	2.564***	3.323***	3.248***	3.018***	3.044***
99:M4-06:M9	High	1.473*	1.485*	1.591**	1.360*	1.268
Denmark						
85:M1-99M3 & 06:M10-14M12	Low	1.115	1.163	1.223	1.281*	0.992
99:M4-06:M9	High	0.822	0.411	0.523	0.281	-0.081
Germany						
85:M1-99M3 & 06:M10-14M12	Low	1.740**	1.385*	1.813**	1.918**	2.084**
99:M4-06:M9	High	0.581	0.431	1.099	0.264	0.876
Japan						
85:M1-99M3 & 06:M10-14M12	Low	0.700	2.438***	3.089***	1.874**	3.000***
99:M4-06:M9	High	-0.282	0.958	0.113	0.507	-0.129
Sweden						
85:M1-99M3 & 06:M10-14M12	Low	3.159***	2.558***	2.347***	2.670***	2.362***
99:M4-06:M9	High	1.814**	1.445*	1.182	1.519*	1.273
Switzerland						
85:M1-99M3 & 06:M10-14M12	Low	1.618*	1.756**	2.010**	1.592*	1.822**
99:M4-06:M9	High	1.141	0.198	0.360	-0.086	-0.124
U.K.						
85:M1-99M3 & 06:M10-14M12	Low	1.794**	2.291**	2.336***	2.521***	2.530***
99:M4-06:M9	High	0.748	0.478	1.060	0.779	1.005

Table 7. CW Statistics for Taylor Rule Fundamentals Models:

Deviations from Original Taylor Rule for Different Countries

Country	Deviations	No Smoothing	Smoothing Differential FFR	Smoothing Individual FFR	Smoothing Differential Shadow FFR	Smoothing Individual Shadow FFR
Australia						
1993:M10-2000:M9	Low	-0.662	0.212	1.911**	-0.133	1.581*
83:M3-93:M9&00:M10-14:M12	High	3.384***	3.298***	2.887***	3.238***	2.802***
Canada						
1983:M3-2000:M3	Low	1.699**	2.769***	2.855***	2.132**	2.207**
2000:M4-2014:M12	High	2.475***	2.857***	2.907***	2.775***	2.780***
Japan						
1986:M4-1994:M3	High	-0.362	0.752	0.856	0.688	0.887
1999:M4-2005:M3	Low	-0.658	1.479*	1.748**	0.459	1.493*
2005:M4-2014:M12	Intermediate	1.830**	1.963**	1.802**	1.950**	1.851**
Sweden						
94:M7-02:M3&10:M1-14:M12	Low	2.865***	3.391***	1.748**	2.459***	1.752**
2002:M4-2009:M12	High	2.604***	2.585***	2.708***	2.610***	2.710***
Switzerland No Break	Intermediate	1.878**	1.733**	1.991**	1.501**	1.659**
U.K.						
1983:M3-1988:M6	Intermediate	2.093**	3.036***	2.875***	2.767***	2.657***
1988:M7-2014:M12	Low	1.799**	1.808**	2.133**	2.221**	2.391***

Table 8. CW Statistics for Taylor Rule Fundamentals Models:

Deviations from Modified Taylor Rule for Different Countries

Country	Deviations	No Smoothing	Smoothing Differential FFR	Smoothing Individual FFR	Smoothing Differential Shadow FFR	Smoothing Individual Shadow FFR
Australia						
83:M3-99:M3&09:M9-14:M12	Low	1.744**	1.802**	1.849**	1.667**	1.918**
1999:M4-2009:M6	High	2.889***	2.882***	2.710***	2.872***	2.418***
Canada						
1983:M3-1999:M12	Low	1.707**	2.769***	2.834***	2.135**	2.199**
2000:M1-2006:M12	High	1.387*	1.446*	1.847**	1.285*	1.546*
2007:M1-2014:M12	Intermediate	2.148**	2.522***	2.371***	2.506***	2.392***
Japan						
1993:M10-2005:M3	Low	-0.679	1.431*	1.692*	0.436	1.441*
83:M3-93:M9&05:M4-14:M12	High	1.048	1.819**	1.841**	1.707**	1.861**
Sweden						
94:M4-01:M3&09:M06-14:M12	Low	3.636***	3.428***	2.547***	3.496***	2.511***
2001:M4-2009:M6	High	1.994**	1.924**	2.101**	1.955**	2.125**
Switzerland						
95:M4-00:M6&09:M10-14:M12	Low	-0.076	0.043	1.383*	-0.145	1.435*
2000:M7-2006:M3	Intermediate	1.832**	0.908	-0.273	0.717	-0.655
90:M1-95:M3& 06:M4-09:M9	High	0.769	0.897	1.176	0.894	0.989
U.K.						
90:M1-96:M12&05:M1-14:M12	Low	1.578*	1.698**	1.922**	2.028**	2.147**
1983:M3-1989:M12	High	2.079**	2.792***	2.479***	2.563***	2.278***
1997:M1-2004:M12	Intermediate	0.959	0.673	1.129	1.005	1.283*

Table 9. CW Statistics for Taylor Rule Fundamentals Models: Taylor Rule Principle

Country		Taylor Principle Holds	No Smoothing	Smoothing Differential FFR	Smoothing Individual FFR	Smoothing Differential Shadow FFR	Smoothing Individual Shadow FFR
Australia	1983:M3-1999:M3	Yes	0.811	1.012	1.299*	0.844	1.385*
	1999:M4-2007:M6	Mixed	1.731**	1.799**	1.659**	1.822**	1.115
	2007:M7-2014:M12	No	3.074***	2.921***	2.466***	2.894***	2.520***
Canada	1983:M3-1999:M3	Yes	1.698**	2.763***	2.817***	2.129**	2.190**
	1999:M4-2007:M6	Mixed	1.992**	1.916**	1.829**	1.811**	1.564*
	2007:M7-2014:M12	No	2.083**	2.499***	2.513***	2.466***	2.512***
Denmark	1983:M3-1999:M3	Yes	0.229	0.199	0.343	0.213	0.007
	1999:M4-2007:M6	Mixed	1.094	0.718	0.864	0.686	0.455
	2007:M7-2014:M12	No	1.414*	1.564*	1.482*	1.753**	1.544*
Germany	1983:M3-1999:M3	Yes	-0.190	-0.124	1.056	0.420	1.219
	1999:M4-2007:M6	Mixed	1.016	0.815	0.612	0.715	0.608
	2007:M7-2014:M12	No	2.801***	2.643***	2.326***	2.604***	2.193**
Japan	1983:M3-1999:M3	Yes	-0.585	1.311*	1.803**	0.612	1.744**
	1999:M4-2007:M6	Mixed	0.293	1.154	1.198	0.712	0.929
	2007:M7-2014:M12	No	1.590*	1.747**	1.506*	1.731**	1.541*
Sweden	1983:M3-1999:M3	Yes	0.866	-0.042	-0.206	0.094	-0.254
	1999:M4-2007:M6	Mixed	2.036**	1.676**	1.372*	1.762**	1.526*
	2007:M7-2014:M12	No	3.785***	3.691***	3.185***	3.732***	3.196***
Switzerland	1983:M3-1999:M3	Yes	1.172	1.508*	1.755**	1.354*	1.622*
	1999:M4-2007:M6	Mixed	1.248	0.259	0.292	0.056	-0.157
	2007:M7-2014:M12	No	1.134	0.861	1.034	0.775	0.883
U.K.	1983:M3-1999:M3	Yes	1.675**	2.085**	2.198**	2.219**	2.294**
	1999:M4-2007:M6	Mixed	1.065	0.860	1.295*	1.144	1.269
	2007:M7-2014:M12	No	2.082***	1.986**	2.031**	2.197**	2.173**