Taylor Rule Exchange Rate Forecasting During the Financial Crisis

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Abstract

This paper evaluates out-of-sample exchange rate predictability of Taylor rule models for the euro/dollar exchange rate with real-time data before, during, and after the financial crisis of 2008-2009. While all Taylor rule specifications outperform the random walk with forecasts ending between 2007:Q1 and 2008:Q2, only the specification with both estimated coefficients and the unemployment gap consistently outperforms the random walk from 2007:Q1 through 2012:Q1. Several Taylor rule models that are augmented with credit spreads or financial condition indexes outperform the original Taylor rule models. The performance of the Taylor rule models is superior to the interest rate differentials, monetary, and purchasing power parity models.

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1. Introduction

The past few years have seen a resurgence of academic interest in out-of-sample exchange rate predictability. Gourinchas and Rey (2007), using an external balance model, Engel, Mark, and West (2008), using monetary, Purchasing Power Parity (PPP), and Taylor rule models, and Molodtsova and Papell (2009), using a variety of Taylor rule models, all report successful results for their models vis-à-vis the random walk null. There has even been the first revisionist response. Rogoff and Stavrakeva (2008) criticize the three above-mentioned papers for their reliance on the Clark and West (2006) statistic, arguing that it is not a minimum mean squared forecast error statistic.

An important problem with these papers is that none of them use real-time data that was available to market participants.[1] Unless real-time data is used, the "forecasts" incorporate information that was not available to market participants, and the results cannot be interpreted as successful out-of-sample forecasting. Faust, Rogers, and Wright (2003) initiated research on out-of-sample exchange rate forecasting with real-time data. Molodtsova, Nikolsko-Rzhevskyy, and Papell (2008) use real-time data to estimate Taylor rules for Germany and the U.S. and to forecast the deutsche mark/dollar exchange rate out-of-sample for 1989:Q1 – 1998:Q4. Molodtsova, Nikolsko-Rzhevskyy, and Papell (2011), henceforth MNP (2011), use real-time data to show that inflation and either the output gap or unemployment, variables which normally enter central banks' Taylor rules, can provide evidence of out-of-sample predictability for the U.S. Dollar/Euro exchange rate from 1999 to 2007. Adrian, Etula, and Shin (2011) show that the growth of U.S. dollar-denominated banking sector liabilities forecasts appreciations of the U.S. dollar from 1997 to 2007, but their results break down in 2008 and 2009.

Molodtsova and Papell (2009) conduct out-of-sample exchange rate forecasting with Taylor rule fundamentals, using the variables, including inflation rates and output gaps, which normally comprise Taylor rules. Engel, Mark, and West (2008) propose an alternative methodology for Taylor rule out-of-sample exchange rate forecasting. Using a Taylor rule with pre-specified coefficients for the inflation differential, output gap differential, and real exchange rate, they construct the interest rate differential implied by the policy rule and use the resultant differential for exchange rate forecasting. We use a single equation version of their model, which we call the Taylor rule differentials model.[2] Since there is no evidence that either the Fed or the ECB targets the exchange rate, we do not include the real exchange rate in the forecasting regression for either model.[3]

[1] Gourinchas and Rey (2007) and Engel, Mark, and West (2008) use revised data. Ince (2012) shows that Engel, Mark, and West's results are stronger with real-time data. Molodtsova and Papell (2009) use quasi-real-time data where the trend does not use ex-post observations, but the data itself incorporates revisions.
[2] Taylor (2010b) calls this model the policy rules differential model.
[3] Engel, Mark, and West (2012) extend their panel models to include exchange rate factors. They do not include the real exchange rate in their Taylor rule specification.

Out-of-sample exchange rate forecasting with Taylor rule fundamentals received blogosphere, as well as academic, notice in 2008. On July 28 and September 9, Menzie Chinn posted on Econbrowser a discussion of in-sample estimates of one of the specifications used in an early version of MNP (2011).[4] On August 17, he posted an article by Michael Rosenberg of Bloomberg, who discussed Taylor rule fundamentals as a foreign currency trading strategy. By December 22, however, optimism had turned to pessimism. Once interest rates hit the zero lower bound, they cannot be lowered further. With zero or near-zero interest rates for Japan and the U.S., and predicted near-zero rates for the U.K. and the Euro Area, the prospects for Taylor rule exchange rate forecasting were bleak. A second theme of the post, however, was that there was nothing particularly promising on the horizon. Going back to the monetary model, even in a regime of quantitative easing, faced doubtful prospects for success.[5]

The events of 2007 – 2009 focused the attention of economists on the importance of financial conditions. On August 9, 2007, the spread between the dollar London interbank offer rate (Libor) and the overnight index swap (OIS), an indicator of financial stress in the interbank loan market, jumped from 13 to 40 basis points on concerns that problems in the subprime mortgage market were spreading to the broader mortgage market.[6] The spreads mostly fluctuated between 50 and 90 basis points until September 17, 2008, when they spiked following the announcement that Lehman Brothers had filed for bankruptcy, peaking on October 10 at over 350 basis points. Following the end of the panic phase of the financial crisis in October, 2008, the spread gradually returned to near pre-crisis levels in September 2009. The spread increased again, although not nearly as sharply, in mid-2010 and late-2011. The spreads are depicted in Figure 1.

The deteriorating financial situation in late 2007 and 2008 inspired several proposals for linking monetary policy to financial conditions. Mishkin (2008) argued that, when a financial disruption occurs, the Fed should cut interest rates to offset the negative effects of financial turmoil on aggregate economic activity. McCully and Toloui (2008) suggested that, because of tightened financial conditions, the Fed needed to lower the policy rate by 100 basis points in early February 2008 in order to keep the neutral rate constant. Meyer (2008) argued that the Taylor rule without considerations of financial conditions could not explain aggressive Fed policy in early 2008.

Taylor (2008) proposed adjusting the systematic component of monetary policy by subtracting a smoothed version of the Libor-OIS spread from the interest rate target that would otherwise be determined by deviations of inflation and real GDP from their targets according to the Taylor rule. He argued that such an adjustment, which would have been about 50 basis points in late February 2008,

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[4] The results are contained in Chinn (2008).
[5] These posts are available on http://www.econbrowser.com/ under "exchange rates".
[6] Taylor and Williams (2009) analyze this episode, calling it a "black swan" in the money market. Thornton (2009) discusses the Libor-OIS spread.

would be a more transparent and predictable response to financial market stress than a purely discretionary adjustment.

Curdia and Woodford (2010) modify the Taylor rule with an adjustment for changes in interest rate spreads. Using a Dynamic Stochastic General Equilibrium model with credit frictions, they show that incorporating spreads can improve upon a standard Taylor rule, although the optimal size of the adjustment is smaller than proposed by Taylor and depends on the source of variation in the spreads.

The spread between the euro interbank offer rate (Euribor) and the euro OIS also jumped in August 2007 and spiked in September and October 2008, although not by as much as the U.S. spread. While the Euribor-OIS spread came down in September 2009, it did not return to its pre-crisis levels. During August and December 2010, the spread jumped to as high as 40 basis points and, in December 2011, reached a maximum of 100 basis points. The end-of-quarter Libor-OIS, Euribor-OIS, and the difference between the Libor-OIS and Euribor-OIS spreads are depicted in Figure 1. After the gap between the two spreads narrowed in 2008:Q4, the spread turned against the Euro Area, reaching a maximum in 2011:Q3 and 2011:Q4 before narrowing in 2012:Q1.

This paper investigates out-of-sample exchange rate forecasting during the financial crisis with Taylor rule-based models that incorporate indicators of financial stress. We start with one-quarter-ahead forecasts and estimate models with core inflation and both the output gap and the unemployment gap for the Taylor rule fundamentals and Taylor rule differentials models. When the Libor-OIS/Euribor-OIS differential is included in the forecasting regression, we call the models spread-adjusted Taylor rule fundamentals and differentials models. According to these models, when the Libor-OIS spread increases, the Fed would be expected to either lower the interest rate or, if it had already attained the zero lower bound, engage in quantitative expansion, depreciating the dollar. When the Euribor-OIS spread increases, the ECB would be expected to react similarly, depreciating the Euro. We therefore use the difference between the Libor-OIS and Euribor-OIS spreads in addition to the difference between the U.S. and Euro Area inflation rates and output gaps for out-of-sample forecasting of the Dollar/Euro exchange rate.

Another widely used credit spread is the Ted spread, the three month Libor/three month Treasury spread for the U.S. and the three month Euribor/three month Treasury spread for the Euro Area. As shown is Figure 1, the U.S. Ted spread was generally higher than the Euro Area Ted spread until 2008 and the Ted spread differential was more variable than the Libor-OIS/Euribor-OIS differential. The Euro Area Ted spread spiked with the U.S. Ted spread in 2008:Q3, and so the differential does not display a spike at the peak of the financial crisis. Subsequent to the financial crisis, the Ted spread differential is similar to the Libor-OIS/Euribor-OIS differential. It turns against the Euro Area in 2009, reaches a maximum in 2011:Q3 and 2011:Q4, and narrows in 2012:Q1. We use the difference between the U.S. and Euro Area Ted spreads as an alternative indicator of financial stress.

Financial Conditions Indexes (FCIs) that summarize information about the future state of the economy contained in a number of current financial variables have received considerable attention in recent years. Hatzius, Hooper, Mishkin, Schoenholtz, and Watson (2010) show that FCIs outperform individual financial variables that are considered to be useful leading indicators in their ability to predict the growth of different measures of real economic activity. We therefore augment the Taylor rule by using the difference between the Bloomberg and OECD FCIs for the U.S. and the Euro Area for out-of-sample forecasting of the Dollar/Euro exchange rate.[7] The Bloomberg and OECD FCIs are depicted in Figure 1 where, in contrast to the credit spreads, an increase represents an improvement in financial conditions. Financial conditions deteriorate sharply for both the U.S. and the Euro Area in late 2008, but turn in favor of the U.S. starting in 2009.

Real-time data for the U.S. is available in vintages starting in 1966, with the data for each vintage going back to 1947. Real-time data for the Euro Area, however, is only available in vintages starting in 1999:Q4, with the data for each vintage going back to 1991:Q1. While the euro/dollar exchange rate is only available since the advent of the Euro in 1999, "synthetic" rates are available since 1993. We use rolling regressions to forecast exchange rate changes starting in 1999:Q4, with 26 observations in each regression. Keeping the number of observations constant, we report results ending in 2007:Q1, with 30 forecasts, through 2012:Q1, with 50 forecasts. We report the ratio of the mean squared prediction errors (MSPE) of the linear and random walk models and the CW test statistic of Clark and West (2006).

The Taylor rule fundamentals model with the unemployment gap produces very strong results. The MSPE of the Taylor rule model is smaller than the MSPE of the random walk model and the random walk null can be rejected in favor of the Taylor rule model using the CW test at the 5 percent level for the initial set of forecasts ending in 2007:Q1. As the number of forecasts increases, the MSPE ratios decrease and the strength of the rejections increases, peaking at the 1 percent level in 2008:Q1. In the following quarter, 2008:Q2, the MSPE ratios start to rise and continue to increase through 2009:Q1 (although the rejections continue at the 5 percent level or higher). Starting in mid-2009, the MSPE ratios stabilize and the random walk can be rejected in favor of the Taylor rule model at the 5 percent significance level for all but specifications between 2009:Q2 and 2012:Q1.

The results for the other models are not as strong. For the Taylor rule differentials model with the output gap, the random walk null can be rejected at the 10 percent level or higher from 2007:Q1 to 2008:Q3 and 2009:Q2 to 2009:Q4, but not otherwise. For the Taylor rule fundamentals model with the output gap and the Taylor rule differentials model with the unemployment gap, the random walk null can only be rejected at the 10 percent level or higher from 2007:Q1 to 2008:Q2.

[7] We cannot use the other FCIs considered by Hatzius et al. (2010), because they are only available for the U.S.

A major innovation in this paper is to incorporate indicators of financial stress, measured by the difference between the Libor-OIS and Euribor-OIS spreads, the U.S. and Euro Area Ted spreads, the U.S. and Euro Area Bloomberg FCIs, and the U.S. and Euro Area OECD FCIs, for out-of-sample exchange rate forecasting with Taylor rule models. The strongest results are again for the Taylor rule fundamentals model with the unemployment gap. Using the OECD FCI, the random walk null can be rejected in favor of the linear model alternative at the 5 percent level for all but one set of forecasts, and at the 10 percent level for the remaining forecast. Using the three other indicators, the null can be rejected at the 10 percent level or higher for over half of the forecasts, with the strongest results for the forecasts ending between 2007 and 2009. As with the original Taylor rule model, the augmented Taylor rule differentials model with the output gap is the next most successful, with the random walk null rejected at the 10 percent level or higher for all forecasts using the OECD FCI and at the 10 percent level or higher for over half of the forecasts with the three other indicators. The rejections for the other two augmented models are concentrated in 2007 and 2008.

We proceed to compare the original and augmented models for the two most successful specifications. For the Taylor rule fundamentals models with the unemployment gap, the original model null can be rejected in favor of the augmented model alternative at the five percent level for virtually every set of forecasts ending between 2007:Q1 to 2008:Q2 for all four financial stress indicators. For the forecasts ending between 2008:Q3 and 2012:Q1, however, the original model null is never rejected. For the Taylor rule differentials model with the output gap, there is some evidence in favor of the alternative specification with the Ted spread, Bloomberg FCI, and OECD FCI.

We also compare the out-of-sample performance of the Taylor rule models with the monetary, PPP, and interest rate differentials models. For the interest rate differentials model, the MSPE ratios are below one and the random walk can be rejected with the CW tests from 2007:Q1 to 2008:Q2. Starting with the panic period of the financial crisis in 2008:Q3, the MSPE ratios rise above one and the random walk null can only be rejected for the forecasts ending in 2009:Q1 and 2012:Q1. The monetary and PPP models cannot outperform the random walk for any forecast interval. The evidence of out-of-sample exchange rate predictability is much stronger with the Taylor rule models than with the traditional models.

2. Exchange Rate Forecasting Models

Evaluating exchange rate models out of sample was initiated by Meese and Rogoff (1983), who could not reject the naïve no-change random walk model in favor of the existent empirical exchange rate models of the 1970s. Starting with Mark (1995), the focus of the literature shifted towards deriving a set of long-run fundamentals from different models, and then evaluating out-of-sample forecasts based on the difference between the current exchange rate and its long-run value. Engel, Mark, and West (2008) use the interest rate implied by a Taylor rule, and Molodtsova and Papell (2009) use the variables that enter Taylor rules to evaluate exchange rate forecasts.

2.1 Taylor Rule Fundamentals Model

We examine the linkage between the exchange rate and a set of variables 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

$$i_t = \pi_t + \phi(\pi_t - \overline{\pi}) + \gamma y_t + R \tag{1}$$

where i_t is the target for the short-term nominal interest rate, π_t is the inflation rate, $\overline{\pi}$ is the target level of inflation, y_t is the output gap, the percent deviation of actual real GDP from an estimate of its potential level, and R is the equilibrium level of the real interest rate.[8]

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. The unemployment gap, the difference between the unemployment rate and the natural rate of unemployment, can replace the output gap in Equation (1) as in Blinder and Reis (2005) and Rudebusch (2010). In that case, the coefficient γ would be negative so that the Fed raises the interest rate when the unemployment rate is below the natural rate of unemployment. 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 $\overline{\pi}$ and R in equation (1) can be combined into one constant term, $\mu = R - \phi\overline{\pi}$, which leads to the following equation,

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

where $\lambda = 1 + \phi$. Because $\lambda > 1$, the real interest rate is increased when inflation rises, and so the Taylor principle is satisfied. Following Taylor (2008) and Curdia and Woodford (2010), the original Taylor rule can be modified by subtracting a multiple of the spread between the dollar Libor rate and the OIS rate,

$$i_t = \mu + \lambda\pi_t + \gamma y_t - \delta s_t \tag{3}$$

where s_t is the spread.

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[8] While we do not explicitly incorporate time-varying inflation and/or equilibrium real interest rates, the use of rolling regressions allows for changes in the constant.

We do not incorporate several modifications of the Taylor rule that, following Clarida, Gali, and Gertler (1998), are typically used for estimation. Lagged interest rates are usually included in estimated Taylor rules to account for either (1) partial adjustment of the federal funds rate to the rate desired by the Federal Reserve or (2) desired interest rate smoothing on the part of the Federal Reserve. Since the most successful exchange rate forecasting specifications for the dollar/euro rate in MNP (2011) did not include a lagged interest rate and Walsh (2010) shows that the Federal Reserve lowered the interest rate during the financial crisis faster than would be consistent with interest rate smoothing, we do not include lagged interest rates. The real exchange rate is often included in specifications that involve countries other than the U.S. Since there is no evidence that the ECB uses the real exchange rate as a policy objective and inclusion of the real exchange rate worsens exchange rate forecasts in MNP (2011), we do not include it. Finally, while inflation forecasts are often used on the grounds that Federal Reserve policy is forward looking, there is no publicly available data on Euro Area core inflation forecasts.

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

$$i_t - i_t^* = \alpha + \lambda(\pi_t - \pi_t^*) + \gamma(y_t - y_t^*) - \delta(s_t - s_t^*) + \eta_t \tag{4}$$

where asterisks denote Euro Area variables and α is a constant. It is assumed that the coefficients on inflation and the output gap are the same for the U.S. and the Euro Area, but the inflation targets and equilibrium real interest rates are allowed to differ.[9]

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:[10]

$$\Delta e_{t+1} = \omega - \omega_\pi(\pi_t - \pi_t^*) - \omega_y(y_t - y_t^*) + \omega_s(s_t - s_t^*) + \eta_t \tag{5}$$

where asterisks denote Euro Area variables, ω is a constant, and ω_π, ω_y, and ω_s are positive coefficients. Alternatively, the unemployment gap differential (with opposite sign) can substitute for the output gap differential in Equation (5).

[9] The assumption of equal coefficients is not necessary to produce a forecasting equation, and is made because, in MNP (2010), the results were consistently stronger with homogeneous coefficients than with heterogeneous coefficients.

[10] A more extensive discussion of the link between higher inflation and forecasted exchange rate appreciation can be found in Molodtsova and Papell (2009).

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 (4) and (5) 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 e_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 (4) and (5).[11]

The difference between the U.S. and Euro Area Ted spreads, Bloomberg FCIs, and OECD FCIs can also be used as the measure of the spread differential. An increase in the U.S. spreads relative to the Euro Area spreads would cause forecasted dollar depreciation. Because the FCIs are constructed so that an increase represents an improvement in financial conditions, the sign of the coefficient on the FCI differentials would be negative so that a relative deterioration in U.S. financial conditions would still lead to forecasted dollar depreciation.

2.2 Taylor Rule Differentials Model

Engel, Mark, and West (2008) 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. They posit, rather than estimate, coefficients for the Taylor rule and subtract the interest rate reaction function for the Euro Area from that for the U.S. to obtain implied interest rate differentials,

$$i_t - i_t^* = 2.0(\pi_t - \pi_t^*) + 0.5(y_t - y_t^*) + 0.1(e_t + p^*{}_t - p_t) \quad (6)$$

where the constant is equal to zero assuming that the inflation target and equilibrium real interest rate are the same for the U.S. and the Euro Area. Out-of-sample exchange rate forecasting is conducted using single equation and panel error correction models.[12]

We estimate a variant of the Taylor rule differentials model with two measures of economic activity, OECD estimates of the output gap and the unemployment gap. In order to obtain an implied interest rate differential that corresponds to the implied interest rate differential (6) with the unemployment gap as the measure of real economic activity, we use a coefficient of -1.0. This is consistent with a coefficient of 0.5 on the output gap if the Okun's Law coefficient is 2.0.

[11] We postulate the signs of the coefficients in order to link the Taylor rule forecasting equation to the relevant theoretical and empirical literature. In the empirical work below, we do not impose restrictions on the estimated coefficients for any of the models.

[12] Whether or not the inflation target and equilibrium real interest rate are the same for the U.S. and the Euro Area is irrelevant because there is a constant in their forecasting equation.

The Taylor rule differential model using Taylor's original coefficients would have a coefficient of 1.5 on the inflation differential, 0.5 on the output gap differential, and would not include the real exchange rate.[13] During 2009 and 2010, a number of commentators, most notably Rudebusch (2010), argued that the appropriate output or unemployment 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 coefficients, it is clear that the latter provide a better fit for Fed policy in the 2000s.[14] Since the same argument has not been made for the ECB, we implement this by estimating a Taylor rule differentials model with a coefficient of 1.0 on the output gap (or -2.0 on the unemployment gap) for the U.S. and 0.5 on the output gap (or -1.0 on the unemployment gap) for the ECB,

$$i_t - i_t^* = \alpha + 1.5(\pi_t - \pi_t^*) + 1.0y_t - 0.5y_t^* \tag{7}$$

where α is a constant.

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

$$\Delta e_{t+1} = \omega - \omega_i (1.5(\pi_t - \pi_t^*) + 1.0y_t - 0.5y_t^*) + \eta_t \tag{8}$$

where, as in the Taylor rule fundamentals model, the signs of the coefficients switch and we do not have a link between the magnitudes of the coefficients in (7) and (8). The Taylor rule differentials model can also be augmented with the credit spread or FCI differentials,

$$\Delta e_{t+1} = \omega - \omega_i (1.5(\pi_t - \pi_t^*) + 1.0y_t - 0.5y_t^*) + \omega_s (s_t - s_t^*) + \eta_t \tag{9}$$

where s_t and s_t^* denote the various measures for the U.S. and Euro Area. As with the Taylor rule fundamentals model, the coefficient would be positive for spreads and negative for differentials.

2.3 Interest Rate Differentials Model

We postulate the following exchange rate forecasting equation,

$$\Delta e_{t+1} = \omega - \omega_i (i_t - i_t^*) \tag{10}$$

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.

[13] Engel, Mark, and West (2012) use these coefficients.
[14] Nikolsko-Rzhevskyy and Papell (2011) discuss these issues.

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

$$\Delta e_{t+1} = \omega + \omega_z z_t + v_t, \tag{11}$$

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.

$$f_t = (m_t - m_t^*) - k(y_t - y_t^*) \tag{12}$$

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 (12) into (11), 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,

$$f_t = (p_t - p_t^*) \tag{13}$$

where p_t is the log of the national price level. We substitute the PPP fundamentals (13) into (11), and use the resultant equation for forecasting.

3. Forecast Comparison Based on MSPE

We are interested in comparing the mean squared prediction errors from 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 $E_{t+1}(\varepsilon_t) = 0$

We want to test the null hypothesis that the MSPEs are equal against the alternative that the MSPE of the linear model 2 is smaller than the MSPE of the random walk model 1. Under the null, the population MSPEs are equal. We need to use the sample estimates of the population MSPEs to draw the inference. The procedure introduced by Diebold and Mariano (1995) and West (1996) uses sample MSPEs to construct a t-type statistics, which is assumed to be asymptotically normal.

The ideal test for evaluating exchange rate models out-of-sample does not exist. The null hypothesis for the DMW test is that the MSPE from the random walk model is equal to the MSPE from the linear model, and the alternative hypothesis is the MSPE from the linear model is smaller than the MSPE from the random walk model. Under the null hypothesis of a random walk, however, the MSPE of the linear model will be larger than the MSPE of the random walk model because the parameters, which have no predictive ability by definition, are being estimated. This biases MSPE comparisons towards favoring the random walk model and makes DMW tests undersized, also favoring the random walk model.[15] This is an example of the inappropriate application of MSPE comparisons and DMW tests to nested models, which is relevant because, if the null hypothesis is a random walk and the alternative hypothesis is a linear model, the two models are always nested.

Clark and West (2006) propose an adjustment to the DMW statistic, called the CW statistic, which corrects for the size distortions with nested models under the null. For the CW test, the null hypothesis is that the exchange rate follows a random walk while the alternative hypothesis is that the exchange rate can be described by a linear model. An alternative is to use the DMW statistic with bootstrapped critical values. While these are tests of predictability, they are not tests of forecasting ability. With both statistics, it is possible to reject the random walk null in favor of the linear model alternative even though the MSPE of the random walk is smaller than the MSPE of the linear model.

Clark and West (2007) show that, while the CW statistic is asymptotically normal if the parsimonious model is a random walk, it is not asymptotically normal in general. Even in the latter case, they advocate use of the CW statistic based on simulations which show that, for sufficiently large samples, standard normal critical values will provide actual sizes close to the nominal size.

It is important to understand the distinction between predictability and forecasting ability. We use the term "predictability" as a shorthand for "out-of-sample predictability" in the sense used by Clark and West (2006), rejecting the null of a zero slope in the predictive regression in favor of the alternative of a nonzero slope. The CW methodology tests whether the regression coefficient β is zero rather than whether the sample MSPE from the model-based forecast is smaller than the sample MSPE from the random walk forecast.

[15] McCracken (2007) shows that using standard normal critical values for the DMW statistic results in severely undersized tests, with tests of nominal 0.10 size generally having actual size less than 0.02.

One disquieting aspect of both tests is that it is possible to find evidence of predictability when the MSPE of the random walk forecast is smaller than the MSPE of the linear model forecast. The issue arises because, whether good size is achieved by bootstrapping or adjusting the DMW statistic, the distribution of the critical values is not centered around the point where the two MSPEs are equal. While this is not problematic in the context of testing for predictability, which is a test of whether the regression coefficient β is significantly different from zero, it is problematic in interpreting the results as evidence of forecasting ability, which is a test of whether the MSPE from the model is smaller than the MSPE from the random walk.

In the absence of an ideal test, we report two test statistics: the ratio of the MSPE of the linear model to that of the random walk model and the CW statistic. While rejecting the random walk null in favor of the linear model alternative with the CW statistic provides evidence of predictability for the model and reporting an MSPE ratio below one constitutes evidence that the model forecasts better than the random walk, the test results cannot provide evidence that that the model forecasts significantly better than the random walk.

4. Real-Time Data

We use real-time quarterly data from 1999:Q4 to 2012:Q1 for the United States and the Euro Area. Most of the data is from the OECD Original Release and Revisions Database.[16] The dataset has 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.[17] For each subsequent quarter, the new vintage incorporates revisions to the historical data, thus providing all information known at the time.

For each forecasting regression, we use 26 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. The data for the first vintage starts in 1993:Q1. We use rolling regressions to predict 30 exchange rate changes from 1999:Q4 to 2007:Q1, 31 exchange rate changes from 1999:Q4 to 2007:Q2, etc., up to 50 exchange rate changes from 1999:Q4 to 2012:Q1.[18]

[16] An alternative would be to use Euro Area Business Cycle Network dataset that is now maintained by the ECB Statistical Data Warehouse, but it does not start until 2001.
[17] There is typically a one-quarter lag before data is released, so real-time variables dated time t actually represent data through period $t-1$.
[18] Inoue and Rossi (2011) discuss the robustness of out-of-sample exchange rate forecasting to the size of the forecast window. Since we cannot conduct forecasts before 1999:Q4 and only have 30 exchange rate changes by 2007:Q1, we are unable to test for robustness.

Since we use vintage data, the estimated coefficients are based on revised data, but the forecasts are conducted using real-time data.[19]

We use the core Personal Consumption Expenditure (PCE) index to measure inflation for the U.S. and the core HICP to measure inflation for Euro Area. Real-time U.S. core PCE is from the Philadelphia Fed Real-Time Database for Macroeconomists described in Croushore and Stark (2001). Core PCE inflation has been emphasized by the Fed since 2004, while keeping HICP inflation below 2 percent has been the policy objective of the ECB since its inception. For the core HICP, we use the HICP index for all-items excluding energy and unprocessed food from the Euro Area Real-Time Data available from the ECB Statistical Data Warehouse. Since the first available vintage is 2001:Q1, we assume that the core HICP is not revised during the first five quarters of the sample. Following Taylor (1993), the inflation rate is the rate of inflation over the previous four quarters. Since inflation is released monthly, we use the price indices released in the third month of each quarter to measure quarterly inflation rates.[20]

We construct quarterly measures of the output gap from internal OECD estimates. The data comes from semi-annual issues of the OECD Economic Outlook. Each issue contains past estimates, nowcasts, and future forecasts of annual values of the output gap for OECD countries including the Euro Area. The OECD Economic Outlook is published in June and December of each year. In order to construct quarterly vintages from semiannually released real-time output gap data, we use the nowcast of the output gap for the second and fourth quarter of each year and the forecast of the output gap for the first and third quarter of each year. Since both estimates and forecasts prior to December 2003 are semi-annual, we used quadratic interpolation to obtain real-time quarterly estimates for early vintages.

The unemployment rates are from the OECD Original Release and Revisions Database. As with the inflation rates, the unemployment rates are released monthly and we use the unemployment rate released in the third month of each quarter to measure quarterly unemployment rates. We use the Non-Accelerating Inflation Rate of Unemployment (NAIRU) from semi-annual OECD Economic Outlook issues to construct the unemployment gap for both the U.S. and the Euro Area. As with the output gap, quadratic interpolation is used to transform semiannual NAIRU series into quarterly before December 2003. The OECD Economic Outlook introduced the NAIRU variable in December 2001. For the U.S., we use Congressional Budget Office (CBO) Economic Outlook quarterly estimates of the NAIRU to complement OECD Economic Outlook data. Since there is no counterpart to CBO NAIRU estimates for

[19] 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 50 forecast periods, we do not have that option for this paper.

[20] We do not consider headline inflation because, as the oil price spike raised headline inflation in 2008, the implied Taylor rule interest rate rose sharply above the actual rate for both the U.S. and the Euro area. Bernanke (2010) has emphasized this for the U.S.

the Euro Area, we assume that the Euro Area NAIRU has not been revised in the early vintages prior to December 2001, which does not appear to be a bad approximation for this series.

The nominal exchange rate, defined as the U.S. dollar price of a Euro, is taken from daily exchange rates provided on the PACIFIC Exchange Rate Service website. While the actual exchange rate is only available since the advent of the Euro in 1999, "synthetic" euro rates are available starting in 1993. We use point in time, rather than quarterly averaged, exchange rates to avoid inducing serial correlation in exchange rate changes. We use the end of the third month of each quarter as our exchange rate.

The short-term nominal interest rates, defined as the interest rate in the third month of each 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 price levels for calculating PPP fundamentals are measured by the CPI for the U.S. and HICP the Euro Area. The money supply is measured by seasonally adjusted M3 (broad money) in billions of national currency, and national income is measured by real GDP. Real-time price level, money supply, and real GDP are taken from the OECD Original Release and Revisions Database for both countries.

While data for macroeconomic variables starts in 1993:Q1, data for credit spreads and financial condition indexes is only available from 1999:Q1. Since we want to use the same number of observations to estimate the historical relationship with financial variables as we used with only macroeconomic variables, we start forecasting using indicators of financial stress starting in 2005:Q4 when the entire series of credit spreads or FCIs is available for estimation. Prior to this point, the model without spreads is used to form forecasts for all models. Libor-OIS and Euribor-OIS spreads, the U.S. and Euro Area Ted spreads, and Bloomberg Financial Condition Indexes for the U.S. and Euro Area are obtained from Bloomberg.[21] The data for quarterly OECD Financial Conditions Index is taken from OECD Economic Outlook. We use data from the end of the third month of each quarter for these series.

The Bloomberg and OECD FCIs are constructed very differently. The Bloomberg FCI is an equally weighted average of money, bond, and equity market variables, and includes both the Libor-OIS and the Ted spreads. The OECD FCI is also a weighted average of current financial variables, but includes neither the Libor-OIS nor the Ted spreads. The only variable that is included in both indexes is the High Yield/Treasury spread.

Figure 1 shows credit spreads and financial conditions indexes (graphed on the left hand side) and their differentials (graphed on the right hand side) from 1999:Q1 to 2012:Q1. For the credit spreads, larger numbers indicate more adverse financial conditions while, for the FCIs, larger numbers denote

[21] The Bloomberg data are from Rosenberg (2012). We thank Robert Lawrie for providing the data.

more favorable financial conditions. While both U.S. and Euro Area financial conditions deteriorate during the financial crisis using all four measures, the differentials between the spreads and indexes differ considerably across measures. In particular, as shown in Panel A of Figure 1, the differential between the Libor-OIS and Euribor-OIS spreads spikes up to 114.1 basis points in 2008:Q3. To smooth this abnormal value, we replace 2008:Q3 with the average of 2008:Q2 and 2008:Q4 for the forecasts starting in 2008:Q4. All of the differentials move against the Euro Area in 2010 and 2011.

5. Empirical Results

We evaluate out-of-sample exchange rate forecasting with Taylor rule fundamentals and Taylor rule differentials before, during, and after the financial crisis of 2008-2009. For the purpose of comparison, we also evaluate forecasting performance for interest rate, monetary, and PPP specifications. As discussed in Section 4, we conduct one-quarter-ahead exchange rate forecasts starting at the end of the previous quarter. For example, the forecast for 2008:Q3 predicts the exchange rate change from the end of June to the end of September, using the data on inflation, output gaps, and unemployment gaps that was available to market participants at the time that the forecasts would have been made. This forecast spans what Taylor (2010a) calls the panic period of the crisis in late September of 2008. The forecast for 2008:Q4 predicts the exchange rate change from the end of September to the end of December, corresponding to what Taylor calls the start of the post-panic period.

5.1 Taylor Rule Fundamentals

Panel A of Table 1 presents one-quarter-ahead out-of-sample forecasts of the euro/dollar exchange rate with core inflation and two measures of real economic activity. The first column reports the ratio of out-of-sample MSPEs of the linear model to that of the random walk model and the second column reports the CW statistic. The left panel reports results where economic activity is measured by OECD output gap estimates for the U.S. and the Euro Area, and the right panel depicts results where economic activity is measured by OECD unemployment gap estimates. Real-time quarterly data is used throughout.

The first row reports test statistics for 30 forecasts from 1999:Q4 to 2007:Q1 with rolling regressions, using 26 quarters to represent the historical relationship between the Taylor rule fundamentals and the exchange rate changes. For each subsequent row, an additional forecast is included, so that the last row for 2012:Q1 reports statistics for 50 forecasts, but the rolling regressions still use 26 quarters to represent the historical relationship.

The MSPE ratios for the specification with the unemployment gap start under one with forecasts through 2007:Q1, so the forecast errors of the linear model are smaller than those of the random walk model, and remain under one until 2010:Q2. Under the null hypothesis of a random walk, the MSPE of the linear model will be greater than the MSPE of the random walk model, so this represents favorable evidence for the Taylor rule model. The no predictability null can be rejected using the CW test at the 5 percent level for the forecasts ending in 2007:Q1 and 2007:Q2, at the 1 percent level for the forecasts ending in 2007:Q3 through 2008:Q4, and at a mix of 5 percent and 1 percent levels thereafter. The results are not as successful for the specification with the output gap. While the no predictability null can be rejected at the 5 or 10 percent level for the forecasts ending in 2007:Q1 through 2008:Q2, the null cannot thereafter be rejected at the 10 percent level. The MSPE ratios are below one until 2008:Q2 and above one thereafter.

Some intuition for these results can be found in Panel A of Figure 2, which depicts actual and forecasted exchange rate changes with the output and unemployment gaps. Since the exchange rate is defined as dollars per euro, observations above the zero line represent dollar depreciation, while observations below the zero line represent dollar appreciation. The dollar steadily depreciated against the euro from 2006:Q1 to 2008:Q1. In 2008:Q2, the depreciation turned to appreciation and, in 2008:Q3, the dollar sharply appreciated at the peak of the financial crisis. The dollar/euro rate has remained very volatile, with the largest appreciation in 2010:Q2 and the largest depreciation in 2010:Q3.

The forecasts with the unemployment gap track the actual exchange rate movements very well (albeit by the low standards of out-of-sample exchange rate forecasting) through 2008:Q2. The largest quarterly movement in the dollar/euro rate since 2000 occurred in 2008:Q3, when the dollar appreciated by more than 10 percent. As shown in Figure 2, the Taylor rule specifications predicted continued dollar depreciation while, by definition, the random walk model predicted neither depreciation nor appreciation. Starting in 2009, the Taylor rule model continued to predict dollar depreciation, while the actual exchange rate seesawed between appreciation and depreciation. For the specification with the output gap, the forecasts were less successful through 2007. The model generally predicted dollar appreciation during 2009 and 2010 and dollar depreciation in 2011.

5.2 Taylor Rule Differentials

Following Engel, Mark, and West (2008), we evaluate out-of-sample performance of the Taylor rule differentials model. The results for the Taylor rule differentials model are not as strong as those for the Taylor rule fundamentals model. Panel B of Table 1 presents one-quarter-ahead out-of-sample forecasts of the euro/dollar exchange rate with core inflation and both measures of economic activity. The MSPE ratio is below one and the random walk null can be rejected at the 10 percent level in favor of the Taylor rule differentials model for the initial sample ending in 2007:Q1 when real economic activity is measured by either the output gap or the unemployment gap. The MSPE ratios fall during the early part of the sample through 2008:Q1, rise during the financial crisis through 2009:Q1, and stabilize after the crisis. The evidence of predictability is stronger with the output gap than with the unemployment gap. With the output gap, the no predictability null can be rejected at the 10 percent level or higher for almost all forecasts through 2009:Q4 and at the 5 percent level or higher from 2007:Q3 through 2008:Q2. With the unemployment gap, the null can only be rejected at the 10 percent level or higher through 2008:Q2. The actual and predicted exchange rate changes are illustrated in Panel B of Figure 2. The predicted changes are similar to those with the Taylor rule fundamentals model. The models track the actual changes better than the random walk through 2008:Q2, incorrectly predict dollar depreciation from 2008:Q3 to 2009:Q1, and are mixed thereafter.

5.3 Credit Spreads

The results of out-of-sample Dollar/Euro exchange rate forecasts when the variables that enter the Taylor rule specifications, inflation and output/unemployment gap differentials, are augmented by either the Libor-OIS/Euribor-OIS differential or the U.S./Euro Area Ted spread differential are reported in Tables 2 and 3. Panel A reports the MSPE ratios and CW statistics for the Taylor rule fundamentals model and Panel B reports the results for the Taylor rule differentials model.

The relative performance among the specifications is similar for the models with credit spreads as for the original models. The Taylor rule fundamentals model with the unemployment gap outperforms the Taylor rule fundamentals model with the output gap and the Taylor rule differentials model with the output gap outperforms the Taylor rule differentials model with the unemployment gap, and so the two best performing specifications are the Taylor rule fundamentals model with the unemployment gap and the Taylor rule differentials model with the output gap.

With the Libor-OIS/Euribor-OIS differential augmented Taylor rule fundamentals model with the unemployment gap, the no predictability null hypothesis can be rejected at the 1 percent significance level for the forecasts ending in 2007:Q1 through 2008:Q2, at the 5 percent level for the forecasts ending in 2008:Q3 through 2009:Q1, at the 10 percent level for the forecasts ending in 2009:Q2 through 2010:Q2, and cannot be rejected thereafter. The MSPE ratios are below one from 2007:Q1 to 2008:Q2. The next most successful results are for the Taylor rule differentials model with the output gap, where the MSPE ratios are below one from 2007:Q1 to 2008:Q4 and the null is rejected at the 10 percent level or higher from 2007:Q1 through 2009:Q4. Thereafter, the MSPE ratios rise and the significance level of the rejections falls. For the fundamentals model with the output gap and the differentials model with the unemployment gap, the null can only be rejected through 2008:Q2.

The results are similar when the models are augmented by the U.S./Euro Area Ted spread differential. For the Taylor rule fundamentals model with the unemployment gap, the no predictability null hypothesis can be rejected at the 1 percent significance level for all forecasts ending in 2007:Q1 through 2008:Q2 and at the 5 percent level for almost all forecasts ending in 2008:Q3 through 2010:Q2, with several rejections at the 10 percent level thereafter. For the Taylor rule differentials model with the output gap, the null can be rejected at the 1 percent level for almost all forecasts ending in 2007:Q1 through 2008:Q2 and at the 5 and 10 percent levels for the forecasts ending in 2008:Q3 through 2010:Q2. For the fundamentals model with the output gap and the differentials model with the unemployment gap, the null can only be rejected through 2008:Q2.

Actual and predicted exchange rate changes for the models augmented by credit spreads are illustrated in Panel A of Figure 3. In order to conserve space, the results are depicted only for one of the most successful specification, the Taylor rule fundamentals model with the unemployment gap. Because of the limited span of the credit spread data, the predicted exchange rate changes with and without the spreads are the same through 2005:Q3. Thereafter, the augmented models with the spreads show much more variability than the original models without the spreads.

5.4 Financial Conditions Indexes

The results of out-of-sample exchange rate forecasts when the Taylor rule specifications are augmented by either the Bloomberg FCI differentials or the OECD FCI differentials are reported in Tables 4 and 5. Panel A reports the MSPE ratios and CW statistics for the Taylor rule fundamentals model and Panel B reports the results for the Taylor rule differentials model.

The relative performance among the specifications with the OECD FCI differential is similar to the original models and the models with credit spreads. The Taylor rule fundamentals model with the unemployment gap outperforms the fundamentals model with the output gap, the Taylor rule differentials model with the output gap outperforms the differentials model with the unemployment gap, and the best performing specification is the Taylor rule fundamentals model with the unemployment gap. The relative performance is more balanced across specifications for the models augmented with the Bloomberg FCI.

The most consistent evidence across specifications of out-of-sample exchange rate predictability is obtained using the models augmented by the Bloomberg FCI differential. Using the Taylor rule differentials model with the output gap, the no predictability null hypothesis can be rejected at the 5 percent significance level or higher for almost all of the forecasts ending in 2007:Q1 through 2010:Q4 and at the 10 percent level for the forecasts ending in 2011:Q3 through 2012:Q1. For the Taylor rules fundamentals model with either the output or the unemployment gap, the null can be rejected at the 1 percent level for all forecasts ending in 2007:Q1 through 2008:Q2 and at the 10 percent level or higher for virtually all forecasts ending in 2008:Q3 through 2010:Q4 while, for the differentials model with the unemployment gap, the null can be rejected at the 5 percent level from 2007:Q1 through 2008:Q4.

The results are less consistent when the models are augmented by the OECD FCI differential. For the Taylor rule fundamentals model with the unemployment gap, the no predictability null hypothesis can be rejected at the 1 percent significance level for the forecasts ending in 2007:Q1 through 2008:Q3, and at the 5 percent level for almost all forecasts ending in 2008:Q4 through 2012:Q1. For the Taylor rule differentials model with the output gap, the null is rejected at the 10 percent level or higher for almost all of the forecasts from 2007:Q1 through 2012:Q1. The results are weaker for the Taylor rule differentials model with the unemployment gap, where the null is rejected at the 10 percent significance level or higher for the forecasts ending in 2007:Q1 through 2009:Q4. The weakest results are for the Taylor rule fundamentals model with the output gap, where the null is only rejected for the forecasts ending in 2007:Q1 through 2008:Q2. The more consistent rejections using the Bloomberg FCI over the OECD FCI are consistent with the results of Hatzius et al. (2010), who find that the Bloomberg FCI outperforms the OECD FCI for out-of-sample prediction of four measures of real economic activity since 2005.

Actual and predicted exchange rate changes for the models augmented by FCIs are illustrated in Panel B of Figure 3. As with the credit spreads, the results are depicted only for the Taylor rule fundamentals model with the unemployment gap and the predicted exchange rate changes with and without the spreads are the same through 2005:Q3. Thereafter, the augmented models with the FCIs also show much more variability than the original models without the FCIs.

5.5 Original Versus Augmented Taylor Rule Models

We have provided evidence that the null hypothesis of no out-of-sample predictability for the Dollar/Euro exchange rate can be rejected, although not consistently, using the original Taylor rule model, two Taylor rule models augmented by credit spreads, and two Taylor rule models augmented by FCIs. We now investigate whether the original Taylor rule model can be rejected against the four augmented models on the basis of their out-of sample exchange rate forecasts. Since the Taylor rule fundamentals model with the unemployment gap and the Taylor rule differentials model with the output gap had the best performance against the random walk null, we will only consider those two models for the comparison.

The MSPE ratios and CW statistics for tests with the original Taylor rule fundamentals model with the unemployment gap as the null and the augmented fundamentals models as the alternative are presented in Table 6. The results are very consistent across the models. The MSPE ratios are below one and the original model null can be rejected in favor of the augmented model alternative at the 5 percent significance level for virtually all forecasts ending in 2007:Q1 through 2008:Q2 for both spreads and FCIs. For the forecasts ending in 2008:Q3 through 2012:Q2, the MSPE ratios are almost all above one and the null hypothesis is almost never rejected. The superior performance of the models augmented by credit spreads and FCIs prior to the panic phase of the financial crisis is consistent with the proposals, discussed in the Introduction, to augment the Taylor rule as financial conditions worsened in 2007 and early 2008.

The tests with the original Taylor rule differentials model with the output gap as the null and the augmented differentials models as the alternative are presented in Table 7. While there are some rejections for the Ted spread, Bloomberg FCI, and OECD FCI differentials, they are neither particularly strong nor consistent across forecasts. It is not completely clear to us how these results should be evaluated. In Tables 1 – 5, where the null hypothesis was a random walk, the tests perform very well. The null hypothesis was rejected at the 5 percent level or higher in every case where the MSPE ratio was below one as well as in some cases where the MSPE ratio was greater than one. In Table 7, where the null hypothesis is not a random walk, the tests did not perform as well.[22] There are a number of cases where the MSPE ratio is below one and the null is not rejected at the 10 percent level, as well as a few cases where the MSPE ratio is above one and the null is rejected. Given the small size of our sample, it is not clear how applicable are the size and power results in Clark and West (2007). If we adopt a less formal metric and say that we find evidence in favor of the augmented model if either the MSPE ratio is below one or the CW statistic is significant at the 10 percent level, then the results are for the Taylor rule differentials model with the output gap clearer. The model augmented with the Ted spread differentials consistently outperforms the original model, the models augmented with the Bloomberg and OECD FCI differentials usually outperform the original model, while the model augmented with the Libor-OIS/Euribor-OIS FCI differentials does not usually outperform the original model.

5.6 Interest Rate Differentials

The Taylor rule fundamentals and Taylor rule differentials models replace interest rate differentials with either (1) the variables that enter Taylor rules or (2) the interest rates implied by Taylor rules. We now evaluate the performance of out-of-sample exchange rate forecasting using the interest rate differentials themselves.

The results are shown in Table 8. The MSPE ratio is below one for the forecast intervals ending between 2007:Q1 and 2008:Q2, attaining its lowest point in 2008:Q1. The ratio rises between 2008:Q1 and 2008:Q4 and is greater than one for all but one of the intervals ending between 2008:Q3 and 2012:Q1. Using the CW test, the null hypotheses of equal predictability can be rejected at the 5 percent significance level for all forecast intervals ending between 2007:Q1 and 2008:Q2, as well as for the forecast ending in 2009:Q1. For the other forecast intervals ending between 2008:Q3 and 2011:Q4, however, the equal predictability null cannot be rejected at even the 10 percent significance level. For the forecast interval ending in 2012:Q1, the null can be rejected at the 10 percent level.

Figure 4 illustrates the results. While the fit between the actual and predicted changes in the exchange rate are visually comparable to those from the Taylor rule models through 2006, the interest rate differentials model is slower to pick up the subsequent appreciation of the euro and performs worse than the others thereafter. The ECB raised its policy rate above 1 percent in 2011:Q3 and 2011:Q4. As depicted in Figure 4, this led to actual and predicted Euro dollar depreciation in 2012:Q1, which may account for the revival of predictability.

[22] This is less of an issue in Table 6.

Prior to the panic phase of the financial crisis, the interest rate differentials model perform about as well as either the Taylor rule fundamentals or the Taylor rule differentials models. This should not be surprising, as this period was the heyday of the carry trade. Once the financial crisis hit and the Fed and ECB lowered interest rates to unprecedented levels for an extended period, both Taylor rule models outperform the interest rate model.

5.7 Monetary and PPP Fundamentals

The attainment of the zero lower bound for the federal funds rate for the U.S. in late 2008, the sharp fall of the money market rate for the Euro Area in early 2009, and quantitative easing for the U.S. starting in 2009 raises the question of whether more conventional specifications, with monetary or PPP fundamentals, might replace the interest rate differentials and Taylor rule models for out-of-sample exchange rate forecasting.

Table 8 reports one-quarter-ahead out-of-sample forecasts of the euro/dollar exchange rate with monetary and PPP fundamentals using the same statistics that were used to evaluate the Taylor rule and interest rate differential models. Results for the monetary model are presented with k equal to 0 and 1. The results for the monetary and PPP models are extremely clear. For all forecast intervals and all specifications, the MSPE ratios are greater than one and the null hypothesis of equal predictability cannot be rejected with the CW test at even the 10 percent significance level. Neither the monetary nor the PPP models provide any evidence whatsoever against the random walk.

Figure 4 depicts actual and forecasted exchange rate changes for the monetary and PPP models. There is very little variation in the forecasted exchange rate changes, and neither model forecasts the depreciation of the dollar from 2002 through 2004. While the models do a little better than the random walk starting in 2007, the improvement is not sufficient to provide any evidence of predictability.

6. Conclusions

Interest rate setting for the Fed and ECB through 2008 can be described, although of course not exactly, by a Taylor rule. When the federal funds rate hit the zero lower bound in late 2008, it was widely assumed that the Taylor rule was no longer relevant for evaluating Fed policy. This assumption was incorrect, as the prescribed Taylor rule interest rate became a key element in the debate in 2009 and 2010 over how much quantitative stimulus the Fed should provide and is becoming an element in the debate over when the Fed should start to raise the interest rate. Similarly, it was assumed that, once the federal funds rate hit the zero lower bound in late 2008 and (especially) when the policy rate for the ECB hit the zero lower bound in late 2009, Taylor rules would cease to be useful for exchange rate forecasting.

In this paper, we evaluate Taylor rule based out-of-sample forecasting for the Dollar/Euro exchange rate in an environment where one, or both, central bank policy rates are at the zero lower bound. We use models with Taylor rule fundamentals, where the coefficients on the variables that normally comprise Taylor rules, inflation and output/unemployment gaps, are estimated, and models with Taylor rule differentials, where the coefficients are pre-specified. For both types of models, we also evaluate forecasts using models that are augmented with credit spreads or financial conditions indexes.

While all of the models outperform the random walk model prior to the onset of the financial crisis, there are large differences in performance during and after the crisis. For the original Taylor rule models that do not incorporate financial conditions, the most successful specification is the fundamentals model with the unemployment gap. With that specification, the models with spreads or FCIs outperform the original model through 2008:Q2, but not thereafter. The second most successful specification is the differentials model with the output gap. With that specification, the models with the Ted spread, Bloomberg FCI, and OECD FCI outperform the original model.

The Taylor rule models are much more successful than other specifications. While the interest rate differentials model provides some evidence of predictability through 2008:Q2, the evidence disappears during the crisis, and the models with monetary and PPP fundamentals cannot outperform the random walk for any sample.

Taylor rules have proven to be successful at describing interest rate setting at the Fed and other central banks. Once policy rates hit the zero lower bound for the U.S. in late 2008 and the Euro Area in late 2009, Taylor rules became prescriptive rather than descriptive. Measures of financial conditions have played an important role in Taylor rule prescriptions during the financial crisis. This paper is the first (to our knowledge) to use prescriptive Taylor rule models in order to analyze out-of-sample exchange rate forecasting during the financial crisis. Using models with either (1) Taylor rule fundamentals and the unemployment gap or (2) Taylor rule differentials and the output gap, we provide more evidence of out-of-sample predictability than with the random walk benchmark, and several models that incorporate measures of financial conditions outperform the original Taylor rule models.

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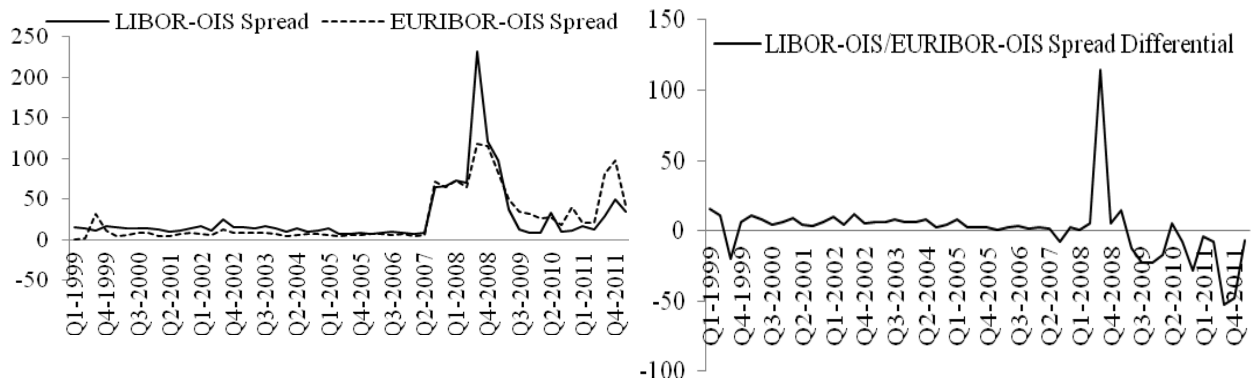
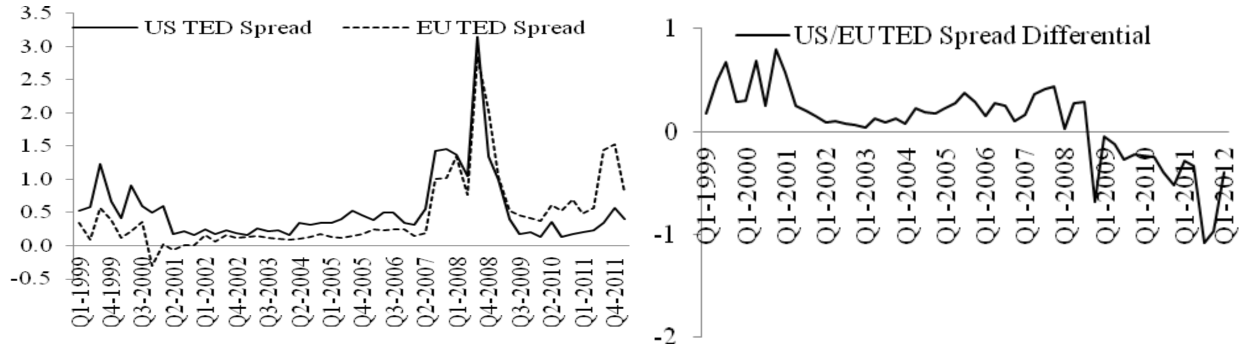
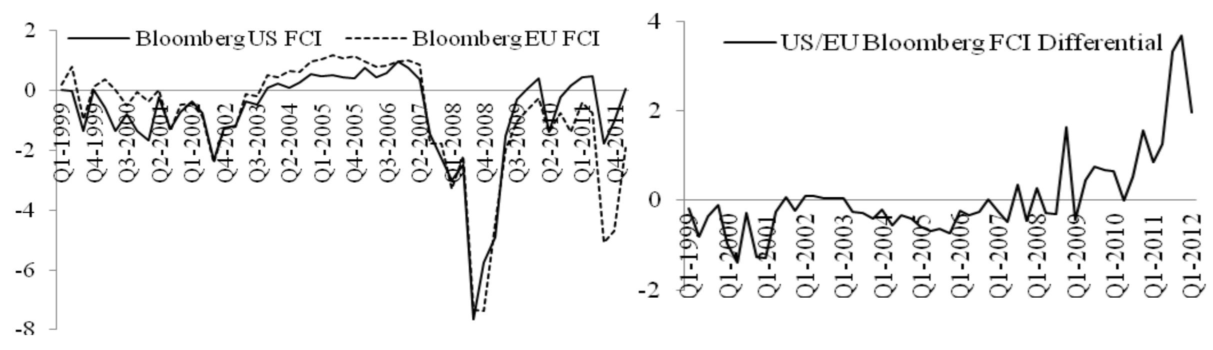


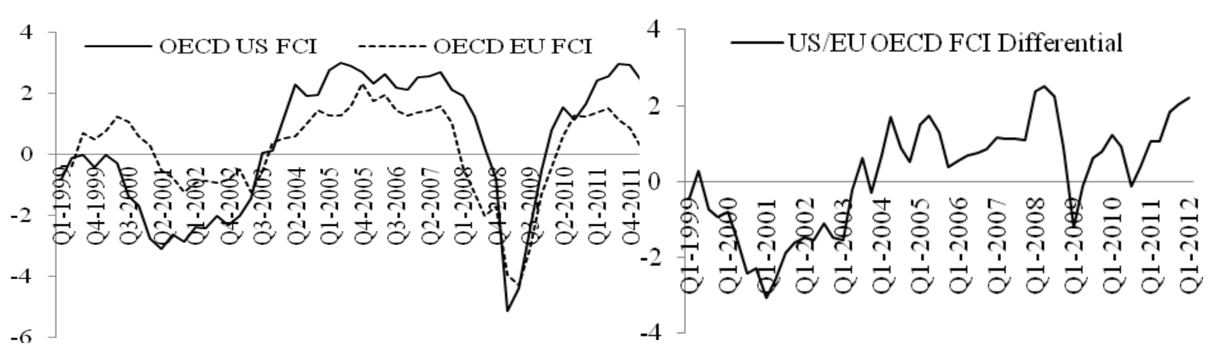
A. LIBOR-OIS and EURIBOR-OIS Spreads



B. TED Spreads for the US and Euro Area

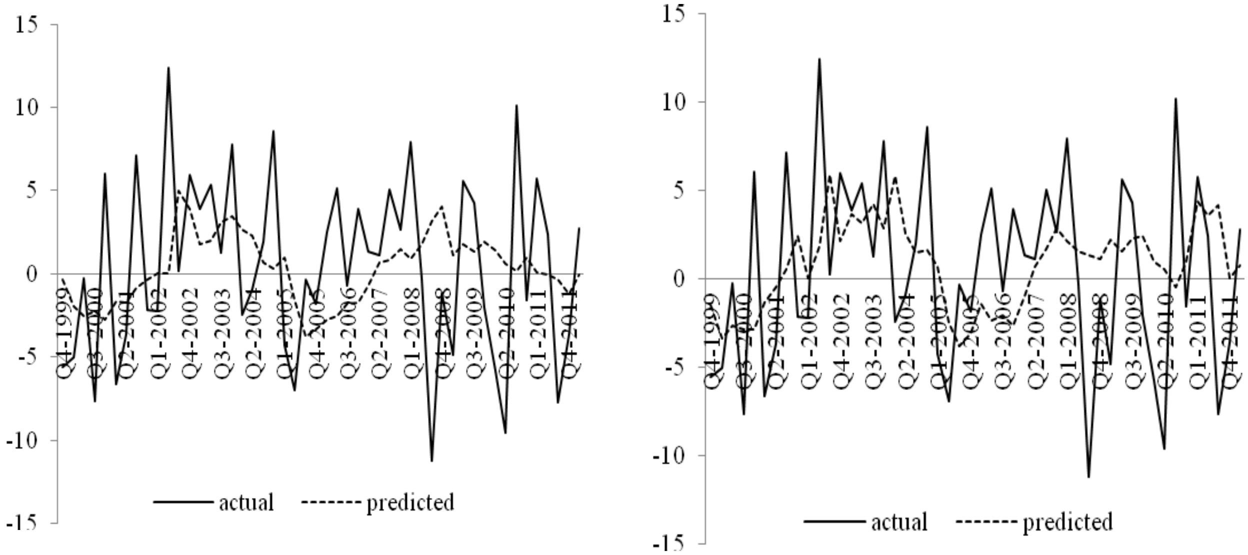


C. Bloomberg US and Euro Area Financial Condition Indexes



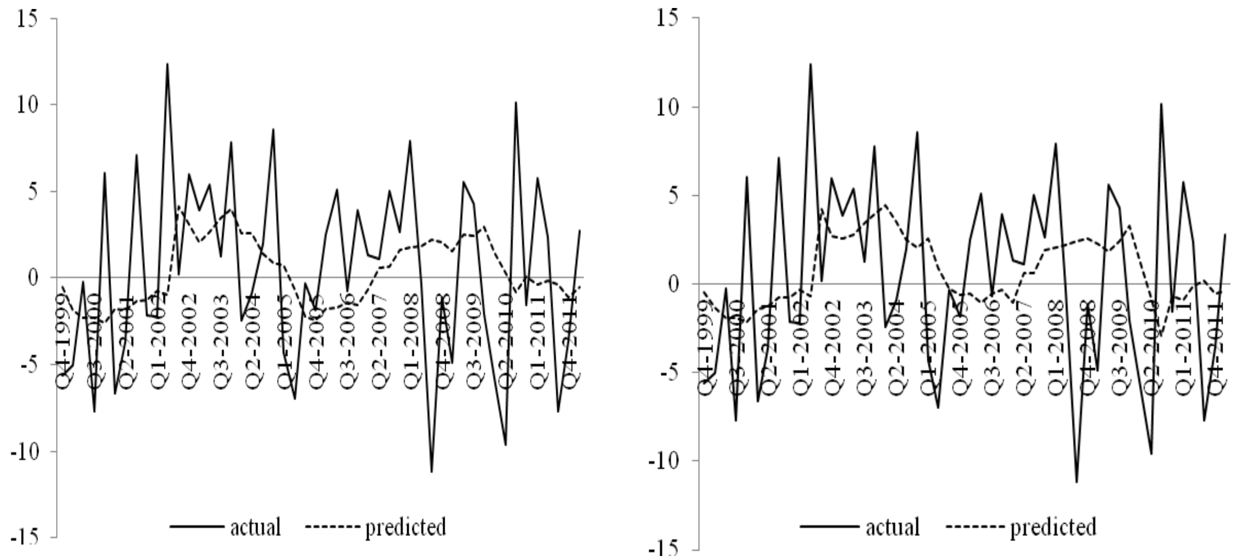
D. OECD Financial Condition Indexes for the US and Euro Area

Figure 1. Credit Spreads and Financial Stress Indexes with their Differentials



OECD Output Gap Unemployment Gap

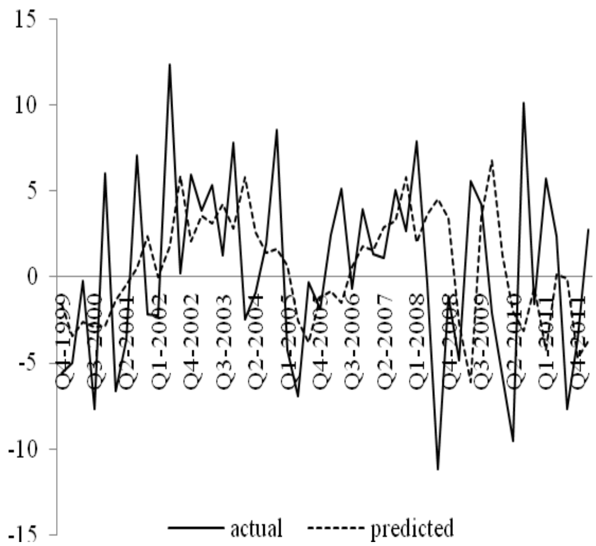
A. Taylor Rule Fundamentals Model

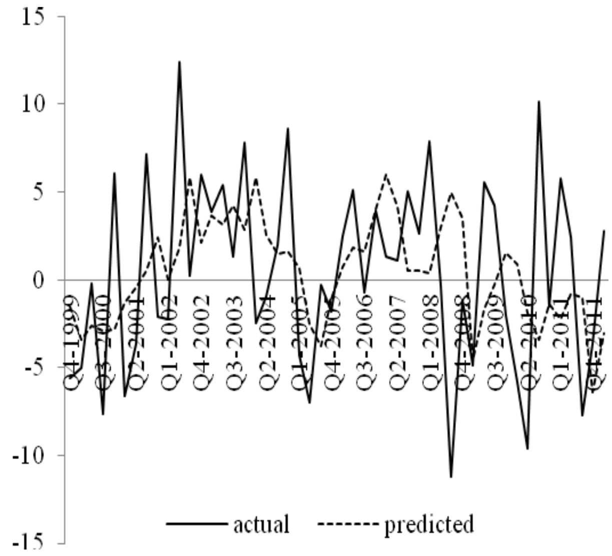


OECD Output Gap Unemployment Gap

B. Taylor Rule Differentials Model

Figure 2. Actual and Predicted Changes in the Dollar/Euro Exchange Rate

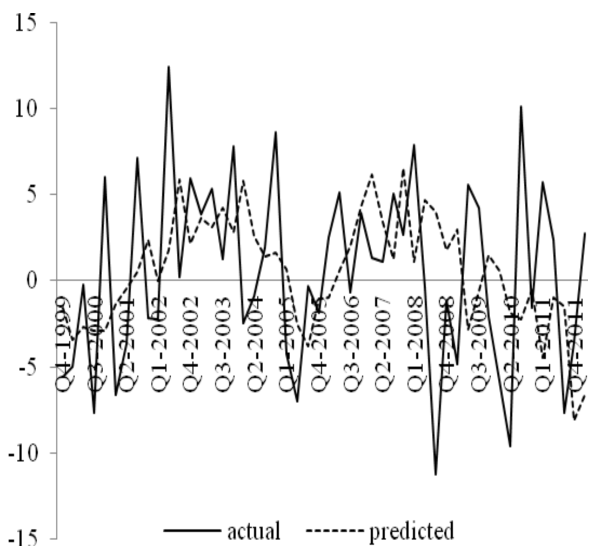


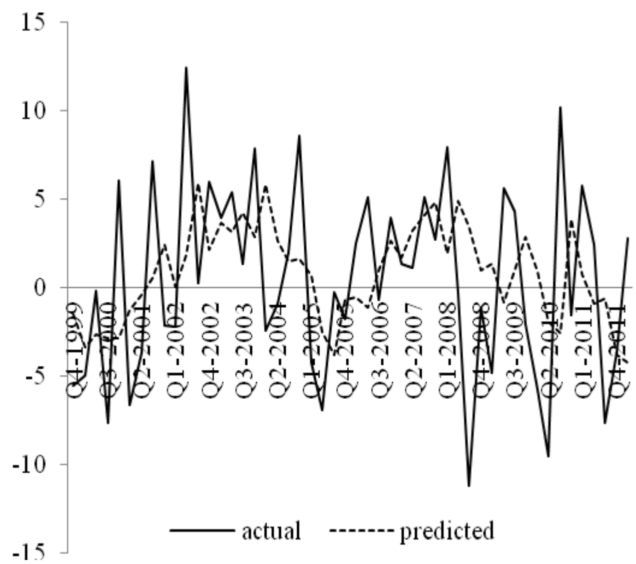


Libor-OIS –Euribor-OIS Spread

Ted Spread

A. Taylor Rule Fundamentals Model with Credit Spreads





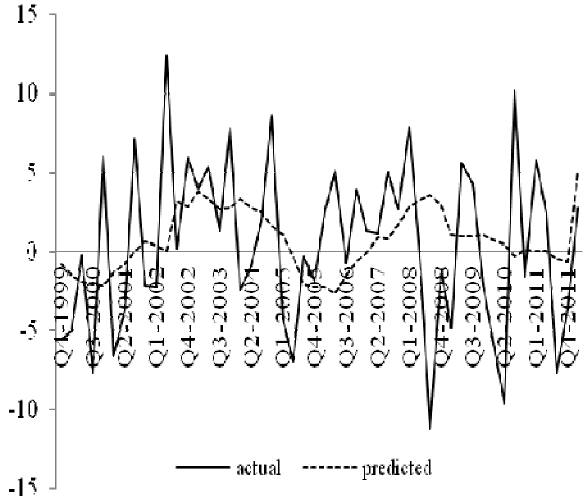
Bloomberg FCI

OECD FCI

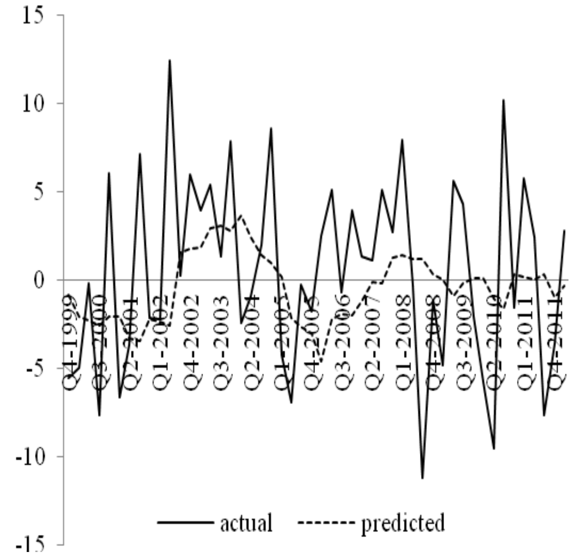
B. Taylor Rule Fundamentals Model with Financial Conditions Indexes

Figure 3. Actual and Predicted Changes in the Dollar/Euro Exchange Rate:

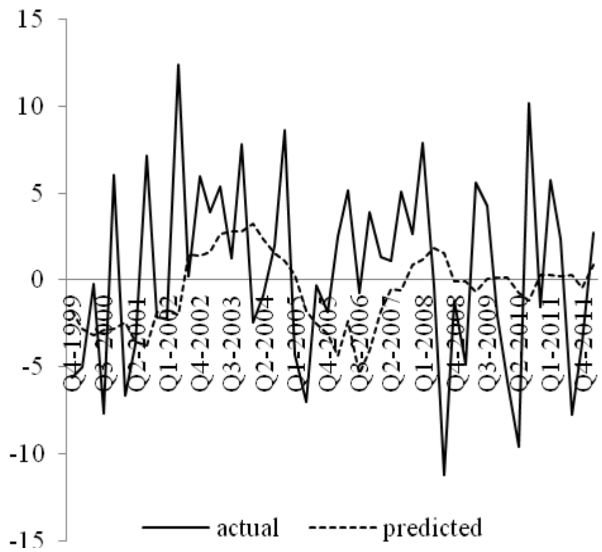
Taylor Rule Fundamentals Model with Unemployment Rate



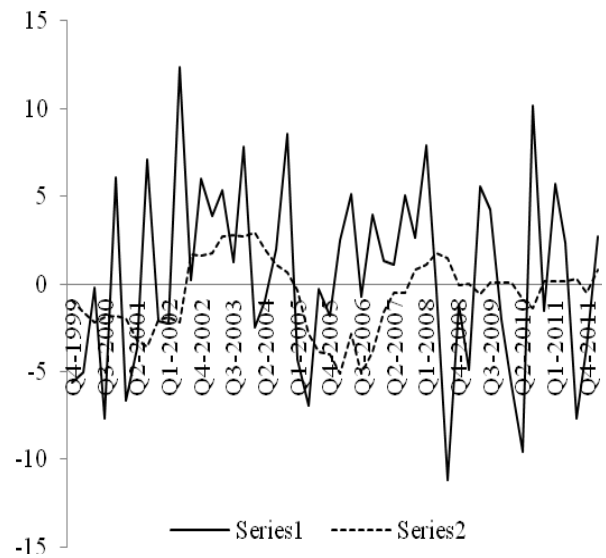
A. Interest Rate Model



B. PPP Model



C. Monetary Model: k = 0



D. Monetary Model: k=1

Figure 4. Actual and Predicted Changes in the Dollar/Euro Exchange Rate
Interest Rate, Monetary, and PPP Models

Table 1. Taylor Rule Models with no Financial Conditions Measures

Forecast Date	MSPE Ratio	CW	MSPE Ratio	CW
	Output Gap		Unemployment Gap	
A. Taylor Rule Fundamentals Model				
2007:Q1	1.000	1.587*	0.962	2.243**
2007:Q2	0.998	1.600*	0.961	2.252**
2007:Q3	0.989	1.679**	0.945	2.389***
2007:Q4	0.982	1.758**	0.937	2.514***
2008:Q1	0.968	1.892**	0.908	2.741***
2008:Q2	0.973	1.876**	0.912	2.722***
2008:Q3	1.057	0.962	0.955	2.353***
2008:Q4	1.083	0.885	0.959	2.326***
2009:Q1	1.093	0.795	0.985	2.106**
2009:Q2	1.074	0.941	0.972	2.229**
2009:Q3	1.064	1.030	0.959	2.366***
2009:Q4	1.075	0.964	0.974	2.271**
2010:Q1	1.089	0.831	0.985	2.168**
2010:Q2	1.091	0.744	0.995	2.071**
2010:Q3	1.082	0.766	1.004	1.976**
2010:Q4	1.085	0.742	1.007	1.950**
2011:Q1	1.082	0.753	0.984	2.207**
2011:Q2	1.082	0.751	0.981	2.319**
2011:Q3	1.075	0.787	1.039	1.682**
2011:Q4	1.069	0.850	1.039	1.679**
2012:Q1	1.069	0.847	1.037	1.704**
B. Taylor Rule Differentials Model				
2007:Q1	0.963	1.582*	0.987	1.443*
2007:Q2	0.962	1.593*	0.986	1.456*
2007:Q3	0.956	1.656**	0.979	1.519*
2007:Q4	0.949	1.737**	0.971	1.617*
2008:Q1	0.924	1.958**	0.940	1.871**
2008:Q2	0.929	1.941**	0.947	1.852**
2008:Q3	0.994	1.310*	1.015	1.177
2008:Q4	1.003	1.267	1.027	1.125
2009:Q1	1.020	1.132	1.054	0.926
2009:Q2	0.999	1.332*	1.035	1.081
2009:Q3	0.985	1.486*	1.021	1.233
2009:Q4	1.005	1.377*	1.043	1.118
2010:Q1	1.023	1.223	1.056	1.003
2010:Q2	1.026	1.172	1.039	1.117
2010:Q3	1.038	1.028	1.088	0.603
2010:Q4	1.038	1.026	1.086	0.618
2011:Q1	1.040	0.990	1.093	0.544
2011:Q2	1.041	0.983	1.093	0.541
2011:Q3	1.035	1.028	1.091	0.522
2011:Q4	1.030	1.088	1.087	0.548
2012:Q1	1.032	1.063	1.089	0.531

Notes: The table reports the ratio of the out-of-sample MSPEs of the Taylor rule models to that of the random walk model and the CW statistic for the test of equal predictability between the two models. The left column reports results where economic activity is measured by OECD output gap estimates for the U.S. and the Euro Area and the right column depicts results where economic activity is measured by the unemployment gap. *, **, and *** denote test statistics significant at 10, 5, and 1% level, respectively, based on standard normal critical values for the CW statistic. The first row in each panel reports test statistics for 30 forecasts from 1999:Q4 to 2007:Q1 with rolling regressions, using a 26-quarter window. For each subsequent row, an additional forecast is included, so that the last row for 2012:Q1 reports statistics for 50 forecasts, but the rolling regressions still use a 26-quarter window.

Table 2. Taylor Rule Models with Libor-OIS/Euribor-OIS Differentials

Forecast Date	MSPE Ratio	CW	MSPE Ratio	CW
	Output Gap		Unemployment Gap	
A. Taylor Rule Fundamentals Model				
2007:Q1	1.000	1.581*	0.881	2.774***
2007:Q2	0.999	1.598*	0.884	2.830***
2007:Q3	0.984	1.727**	0.860	3.067***
2007:Q4	0.976	1.883**	0.865	3.292***
2008:Q1	0.962	2.014**	0.842	3.518***
2008:Q2	0.968	1.996**	0.860	3.470***
2008:Q3	1.052	1.083	1.003	1.868**
2008:Q4	1.076	1.009	1.022	1.811**
2009:Q1	1.076	0.995	1.003	1.956**
2009:Q2	1.107	0.748	1.103	1.403*
2009:Q3	1.090	1.044	1.085	1.557*
2009:Q4	1.169	0.803	1.154	1.378*
2010:Q1	1.189	0.625	1.164	1.291*
2010:Q2	1.163	0.723	1.122	1.478*
2010:Q3	1.140	0.810	1.169	1.075
2010:Q4	1.039	0.819	1.167	1.085
2011:Q1	1.186	0.460	1.214	0.814
2011:Q2	1.183	0.476	1.212	0.818
2011:Q3	1.173	0.498	1.202	0.823
2011:Q4	1.162	0.665	1.192	0.975
2012:Q1	1.200	0.477	1.215	0.873
B. Taylor Rule Differentials Model				
2007:Q1	0.967	1.554*	0.990	1.422*
2007:Q2	0.966	1.568*	0.989	1.439*
2007:Q3	0.953	1.684**	0.975	1.553*
2007:Q4	0.946	1.850**	0.968	1.716**
2008:Q1	0.921	2.073**	0.938	1.962**
2008:Q2	0.927	2.054**	0.947	1.941**
2008:Q3	0.990	1.443*	1.014	1.267
2008:Q4	0.999	1.402*	1.027	1.214
2009:Q1	1.013	1.290*	1.059	0.973
2009:Q2	1.015	1.265*	1.051	1.032
2009:Q3	1.006	1.603*	1.051	1.415*
2009:Q4	1.092	1.324*	1.124	1.185
2010:Q1	1.110	1.165	1.138	1.057
2010:Q2	1.091	1.253	1.111	1.191
2010:Q3	1.085	1.240	1.147	0.797
2010:Q4	1.083	1.259	1.145	0.811
2011:Q1	1.132	0.861	1.192	0.487
2011:Q2	1.131	0.867	1.189	0.497
2011:Q3	1.122	0.900	1.186	0.464
2011:Q4	1.112	1.022	1.175	0.615
2012:Q1	1.130	0.906	1.198	0.491

Notes: The table reports the ratio of the out-of-sample MSPEs of the Taylor rule models augmented with the Libor-OIS/Euribor-OIS differential to that of the random walk model and the CW statistic for the test of equal predictability between the two models. Also see notes to Table 1.

Table 3. Taylor Rule Models with the U.S./Euro Area Ted Spread Differential

Forecast Date	MSPE Ratio	CW	MSPE Ratio	CW
	Output Gap		Unemployment Gap	
A. Taylor Rule Fundamentals Model				
2007:Q1	0.921	2.706***	0.856	3.461***
2007:Q2	0.926	2.781***	0.866	3.542***
2007:Q3	0.942	2.621***	0.864	3.587***
2007:Q4	0.961	2.460***	0.862	3.598***
2008:Q1	0.975	3.337***	0.865	3.650***
2008:Q2	0.978	2.321***	0.878	3.602***
2008:Q3	1.078	1.104	1.032	1.735**
2008:Q4	1.105	1.025	1.052	1.679**
2009:Q1	1.095	1.090	1.027	1.902**
2009:Q2	1.084	1.160	1.047	1.769**
2009:Q3	1.082	1.162	1.048	1.753**
2009:Q4	1.083	1.148	1.056	1.711**
2010:Q1	1.081	1.145	1.065	1.640*
2010:Q2	1.052	1.347*	1.032	1.827**
2010:Q3	1.102	0.805	1.092	1.313*
2010:Q4	1.100	0.829	1.090	1.336*
2011:Q1	1.119	0.657	1.111	1.185
2011:Q2	1.120	0.644	1.114	1.164
2011:Q3	1.109	0.699	1.099	1.242
2011:Q4	1.099	0.839	1.094	1.449*
2012:Q1	1.115	0.733	1.112	1.356*
B. Taylor Rule Differentials Model				
2007:Q1	0.881	2.405***	0.942	2.083**
2007:Q2	0.882	2.460***	0.944	2.141**
2007:Q3	0.896	2.358***	0.956	2.049**
2007:Q4	0.902	2.310**	0.963	1.997**
2008:Q1	0.889	2.477***	0.956	2.077**
2008:Q2	0.892	2.461***	0.962	2.059**
2008:Q3	0.975	1.550*	1.038	1.217
2008:Q4	0.986	1.502*	1.049	1.169
2009:Q1	0.985	1.514*	1.076	0.962
2009:Q2	0.970	1.656**	1.053	1.160
2009:Q3	0.961	1.751**	1.037	1.342*
2009:Q4	0.969	1.692**	1.058	1.234
2010:Q1	0.979	1.609*	1.080	1.047
2010:Q2	0.967	1.741**	1.060	1.170
2010:Q3	1.016	1.196	1.110	0.642
2010:Q4	1.014	1.233	1.108	0.677
2011:Q1	1.037	1.030	1.127	0.504
2011:Q2	1.037	1.027	1.127	0.500
2011:Q3	1.031	1.066	1.121	0.508
2011:Q4	1.024	1.164	1.111	0.667
2012:Q1	1.035	1.076	1.130	0.548

Notes: The table reports the ratio of the o8ut-of-sample MSPEs of the Taylor rule models augmented with the U.S./Euro Area Ted Spread Differential to that of the random walk model and the CW statistics for the test of equal predictability between the two models. Also see notes to Table 1.

Table 4. Taylor Rule Models with the Bloomberg Financial Conditions Index Differential

Forecast Date	MSPE Ratio	CW	MSPE Ratio	CW
	Output Gap		Unemployment Gap	
	A. Taylor Rule Fundamentals Model			
2007:Q1	0.944	2.500***	0.885	3.236***
2007:Q2	0.946	2.560***	0.891	3.302***
2007:Q3	0.943	2.601***	0.880	3.418***
2007:Q4	0.944	2.835***	0.892	3.657***
2008:Q1	0.941	2.898***	0.881	3.806***
2008:Q2	0.959	2.856***	0.910	3.741***
2008:Q3	1.040	1.764**	1.028	2.205**
2008:Q4	1.063	1.682**	1.036	2.170**
2009:Q1	1.129	1.212	1.072	1.920**
2009:Q2	1.104	1.407*	1.108	1.666**
2009:Q3	1.103	1.399*	1.111	1.631*
2009:Q4	1.105	1.382*	1.119	1.588*
2010:Q1	1.101	1.389*	1.122	1.540*
2010:Q2	1.069	1.586*	1.086	1.730**
2010:Q3	1.078	1.445*	1.118	1.393*
2010:Q4	1.076	1.478*	1.116	1.402*
2011:Q1	1.131	1.012	1.166	1.055
2011:Q2	1.134	0.989	1.170	1.029
2011:Q3	1.118	1.079	1.148	1.149
2011:Q4	1.110	1.298*	1.151	1.409*
2012:Q1	1.165	1.037	1.207	1.191
	B. Taylor Rule Differentials Model			
2007:Q1	0.914	2.310**	0.969	1.966**
2007:Q2	0.915	2.361***	0.970	2.017**
2007:Q3	0.914	2.390***	0.967	2.046**
2007:Q4	0.917	2.620***	0.970	2.281***
2008:Q1	0.906	2.764***	0.955	2.424***
2008:Q2	0.925	2.724***	0.978	2.386***
2008:Q3	0.987	2.024**	1.035	1.714**
2008:Q4	0.994	1.981**	1.043	1.670**
2009:Q1	1.061	1.472*	1.149	0.988
2009:Q2	1.034	1.705**	1.120	1.208
2009:Q3	1.024	1.796**	1.105	1.331*
2009:Q4	1.034	1.733**	1.122	1.248
2010:Q1	1.039	1.677**	1.131	1.152
2010:Q2	1.023	1.793**	1.104	1.292
2010:Q3	1.029	1.711**	1.128	0.984
2010:Q4	1.027	1.743**	1.126	1.004
2011:Q1	1.081	1.257	1.174	0.644
2011:Q2	1.082	1.239	1.175	0.630
2011:Q3	1.071	1.311*	1.160	0.700
2011:Q4	1.063	1.512*	1.155	0.957
2012:Q1	1.101	1.294*	1.207	0.729

Notes: The table reports the ratio of the out-of-sample MSPEs of the Taylor rule models augmented with the Bloomberg Financial Conditions Index Differential to that of the random walk model and the CW statistics for the test of equal predictability between the two models. Also see notes to Table 1.

Table 5. Taylor Rule Models with the OECD Financial Conditions Index Differential

Forecast Date	MSPE Ratio	CW	MSPE Ratio	CW
	Output Gap		Unemployment Gap	
	A. Taylor Rule Fundamentals Model			
2007:Q1	0.993	1.594*	0.872	2.865***
2007:Q2	0.991	1.629*	0.877	2.927***
2007:Q3	0.968	1.841**	0.850	3.183***
2007:Q4	0.960	1.967**	0.848	3.382***
2008:Q1	0.943	2.125**	0.829	3.598***
2008:Q2	0.964	2.092**	0.861	3.537***
2008:Q3	1.062	1.031	0.966	2.327***
2008:Q4	1.063	1.025	0.969	2.305**
2009:Q1	1.078	0.910	0.984	2.195**
2009:Q2	1.062	1.023	0.994	2.117**
2009:Q3	1.053	1.091	0.987	2.173**
2009:Q4	1.062	1.040	1.006	2.076**
2010:Q1	1.076	0.915	1.016	1.991**
2010:Q2	1.035	0.895	0.986	2.198**
2010:Q3	1.062	0.935	1.033	1.727**
2010:Q4	1.092	0.819	1.054	1.644*
2011:Q1	1.076	0.970	1.047	1.696**
2011:Q2	1.081	0.927	1.050	1.667**
2011:Q3	1.067	1.038	1.041	1.725**
2011:Q4	1.058	1.256	1.032	1.877**
2012:Q1	1.074	1.141	1.161	1.711**
	B. Taylor Rule Differentials Model			
2007:Q1	0.967	1.547*	1.007	1.338*
2007:Q2	0.967	1.555*	1.006	1.343*
2007:Q3	0.956	1.650**	0.997	1.411**
2007:Q4	0.949	1.730**	0.990	1.497**
2008:Q1	0.931	1.907**	0.969	1.672**
2008:Q2	0.939	1.887**	0.976	1.654**
2008:Q3	0.980	1.517*	0.999	1.440*
2008:Q4	0.979	1.555*	0.999	1.492*
2009:Q1	0.990	1.461*	1.003	1.458*
2009:Q2	0.980	1.561*	1.012	1.365*
2009:Q3	0.971	1.660**	1.006	1.425*
2009:Q4	0.986	1.563*	1.023	1.314*
2010:Q1	1.001	1.418*	1.030	1.237
2010:Q2	0.994	1.488*	1.000	1.499*
2010:Q3	1.004	1.372*	1.053	0.866
2010:Q4	1.028	1.246	1.069	0.785
2011:Q1	1.018	1.366*	1.063	0.833
2011:Q2	1.021	1.327*	1.067	0.795
2011:Q3	1.014	1.406*	1.059	0.854
2011:Q4	1.005	1.617*	1.049	1.066
2012:Q1	1.029	1.420*	1.079	0.876

Notes: The table reports the ratio of the out-of-sample MSPEs of the Taylor rule models augmented with the OECD Financial Conditions Index differential to that of the random walk model and the CW statistics for the test of equal predictability between the two models. Also see notes to Table 1.

Table 6. Original versus Augmented Taylor Rule Models:

Taylor Rule Fundamentals Model with Unemployment Gap

Forecast Date	MSPE Ratio	CW	MSPE Ratio	CW
	LIBOR-OIS/EURIBOR-OIS		TED Spread	
2007:Q1	0.916	1.692**	0.889	2.002**
2007:Q2	0.920	1.720**	0.901	2.024**
2007:Q3	0.910	1.892**	0.914	1.938**
2007:Q4	0.923	1.868**	0.921	1.944**
2008:Q1	0.927	1.852**	0.953	1.713**
2008:Q2	0.944	1.692**	0.963	1.655**
2008:Q3	1.050	0.225	1.080	0.647
2008:Q4	1.066	0.125	1.097	0.573
2009:Q1	1.018	0.654	1.043	1.031
2009:Q2	1.136	0.138	1.078	0.870
2009:Q3	1.132	0.175	1.093	0.810
2009:Q4	1.186	-0.104	1.085	0.853
2010:Q1	1.122	-0.134	1.081	0.855
2010:Q2	1.128	0.217	1.037	1.102
2010:Q3	1.164	0.134	1.087	0.721
2010:Q4	1.059	-0.084	1.082	0.782
2011:Q1	1.234	-0.226	1.129	0.685
2011:Q2	1.236	-0.179	1.136	0.736
2011:Q3	1.157	0.364	1.057	1.165
2011:Q4	1.147	0.534	1.053	1.348*
2012:Q1	1.172	0.440	1.072	1.277
	Bloomberg FCI		OECD FCI	
2007:Q1	0.920	1.850**	0.907	1.717**
2007:Q2	0.927	1.869**	0.912	1.744**
2007:Q3	0.932	1.836**	0.900	1.947**
2007:Q4	0.952	1.818**	0.906	1.932**
2008:Q1	0.971	1.678**	0.913	1.885**
2008:Q2	0.999	1.546*	0.944	1.670**
2008:Q3	1.077	0.762	1.011	0.795
2008:Q4	1.080	0.738	1.011	0.800
2009:Q1	1.089	0.643	0.999	0.929
2009:Q2	1.141	0.353	1.023	0.706
2009:Q3	1.159	0.266	1.030	0.650
2009:Q4	1.149	0.325	1.033	0.607
2010:Q1	1.139	0.358	1.031	0.611
2010:Q2	1.091	0.681	0.991	1.021
2010:Q3	1.113	0.413	1.029	0.556
2010:Q4	1.108	0.464	1.046	0.426
2011:Q1	1.186	0.296	1.064	0.341
2011:Q2	1.193	0.364	1.071	0.426
2011:Q3	1.104	0.945	1.002	1.008
2011:Q4	1.108	1.198	0.993	1.169
2012:Q1	1.164	1.039	1.024	1.035

Notes: The table reports the ratio of the out-of-sample MSPEs of the Taylor rule models augmented with credit spreads or FCIs to that of the original Taylor rule model and the CW statistic for the test of equal predictability between the two models. Also see notes to Table 1.

Table 7. Original versus Augmented Taylor Rule Models:

Taylor Rule Differentials Model with Output Gap

Forecast Date	MSPE Ratio	CW	MSPE Ratio	CW
	LIBOR-OIS/EURIBOR-OIS		TED Spread	
2007:Q1	1.004	-0.298	0.914	1.977**
2007:Q2	1.004	-0.278	0.917	2.011**
2007:Q3	0.998	0.399	0.937	1.733**
2007:Q4	0.997	0.794	0.951	1.640*
2008:Q1	0.996	0.880	0.962	1.504*
2008:Q2	0.998	0.755	0.960	1.548*
2008:Q3	0.996	0.948	0.981	1.274
2008:Q4	0.996	1.017	0.983	1.252
2009:Q1	0.992	1.300*	0.966	1.524*
2009:Q2	1.016	-0.180	0.971	1.442*
2009:Q3	1.022	0.532	0.976	1.380*
2009:Q4	1.086	-0.618	0.965	1.571*
2010:Q1	1.085	-0.680	0.958	1.714**
2010:Q2	1.063	-0.296	0.942	1.980**
2010:Q3	1.046	-0.011	0.979	1.220
2010:Q4	1.044	0.041	0.977	1.288*
2011:Q1	1.088	-0.590	0.996	0.981
2011:Q2	1.087	-0.564	0.997	0.976
2011:Q3	1.084	-0.573	0.997	0.982
2011:Q4	1.080	-0.467	0.994	1.033
2012:Q1	1.095	-0.665	1.003	0.905
	Bloomberg FCI		OECD FCI	
2007:Q1	0.949	1.767**	1.004	-1.271
2007:Q2	0.952	1.798**	1.004	-1.333
2007:Q3	0.957	1.739**	1.001	-0.043
2007:Q4	0.967	1.865**	1.001	-0.048
2008:Q1	0.980	1.683**	1.007	-0.832
2008:Q2	0.996	1.522*	1.011	-1.157
2008:Q3	0.993	1.582*	0.986	0.631
2008:Q4	0.991	1.607*	0.976	1.177
2009:Q1	1.040	0.822	0.970	1.365*
2009:Q2	1.036	0.885	0.981	1.072
2009:Q3	1.040	0.836	0.986	0.958
2009:Q4	1.029	0.987	0.981	1.118
2010:Q1	1.016	1.149	0.979	1.211
2010:Q2	0.997	1.396*	0.969	1.511*
2010:Q3	0.991	1.490*	0.967	1.637*
2010:Q4	0.989	1.550*	0.991	1.209
2011:Q1	1.039	0.780	0.978	1.543*
2011:Q2	1.040	0.762	0.981	1.456*
2011:Q3	1.035	0.811	0.979	1.532*
2011:Q4	1.032	0.983	0.975	1.779**
2012:Q1	1.067	0.642	0.997	1.223

Notes: The table reports the ratio of the out-of-sample MSPEs of the Taylor rule models augmented with credit spreads or FCIs to that of the original Taylor rule model and the CW statistic for the test of equal predictability between the two models. Also see notes to Table 1.

Table 8. Interest Rate, Monetary, and PPP Models

Forecast Date	MSPE Ratio	CW	MSPE Ratio	CW
	A. Interest Rate Model		B. PPP Model	
2007:Q1	0.954	1.773**	1.103	0.768
2007:Q2	0.953	1.781**	1.103	0.766
2007:Q3	0.952	1.803**	1.103	0.749
2007:Q4	0.946	1.875**	1.096	0.798
2008:Q1	0.919	2.123**	1.066	0.953
2008:Q2	0.931	2.096**	1.068	0.946
2008:Q3	1.018	1.125	1.088	0.724
2008:Q4	1.027	1.087	1.089	0.718
2009:Q1	0.948	1.981**	1.087	0.716
2009:Q2	1.023	1.106	1.096	0.635
2009:Q3	1.017	1.161	1.096	0.622
2009:Q4	1.022	1.128	1.096	0.619
2010:Q1	1.027	1.072	1.094	0.612
2010:Q2	1.030	1.026	1.071	0.753
2010:Q3	1.035	0.945	1.094	0.488
2010:Q4	1.034	0.947	1.091	0.494
2011:Q1	1.035	0.925	1.092	0.507
2011:Q2	1.037	0.911	1.091	0.495
2011:Q3	1.023	1.057	1.090	0.463
2011:Q4	1.017	1.134	1.084	0.515
2012:Q1	1.019	1.294*	1.085	0.500
	C. Monetary Model: k=0		D. Monetary Model: k=1	
2007:Q1	1.153	0.776	1.170	0.673
2007:Q2	1.154	0.767	1.171	0.665
2007:Q3	1.157	0.721	1.173	0.623
2007:Q4	1.151	0.754	1.167	0.657
2008:Q1	1.120	0.887	1.136	0.787
2008:Q2	1.126	0.877	1.141	0.777
2008:Q3	1.147	0.597	1.159	0.499
2008:Q4	1.147	0.598	1.159	0.500
2009:Q1	1.143	0.601	1.155	0.502
2009:Q2	1.146	0.550	1.157	0.453
2009:Q3	1.143	0.553	1.153	0.457
2009:Q4	1.143	0.548	1.153	0.454
2010:Q1	1.140	0.536	1.149	0.448
2010:Q2	1.119	0.630	1.125	0.566
2010:Q3	1.129	0.452	1.138	0.351
2010:Q4	1.129	0.446	1.138	0.347
2011:Q1	1.124	0.468	1.133	0.362
2011:Q2	1.122	0.476	1.132	0.366
2011:Q3	1.121	0.445	1.130	0.328
2011:Q4	1.117	0.465	1.127	0.355
2012:Q1	1.114	0.499	1.123	0.387

Notes: The table reports the ratio of the out-of-sample MSPEs of the linear model to that of the random walk model and the CW statistics for the test of equal predictability between the two models. , Panel A contains the results for the Interest Rate Model, Panel B contains the results for the PPP Model, and Panels C and D contain the results for the monetary model with income elasticity k=0 and 1, respectively. Also see notes for Table 1.