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Exchange Rate Equations Based on Interest Rate Rules: In-Sample and Out-of-Sample Performance

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Exchange Rate Equations Based on Interest Rate Rules: In-Sample and Out-of-Sample Performance

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Abstract

Using exchange rate data on five currencies vis-à-vis the US dollar, this paper examines the in-sample and out-of-sample performance of exchange rate equations derived from alternative empirical and optimal interest rate rules. These rules could have either homogeneous or heterogeneous response coefficients. Our exercise shows that these exchange rate equations do not offer good in-sample explanatory power consistently across currencies and over time. The relative forecasting performance of these exchange rate equations tend to vary across currencies and over time and bears limited relationship with the relative in-sample performance. When the forecast performance is compared with a random walk model, these exchange rate equations offer no better performance under the usual MSFE criterion but are better when the ability of predicting the direction of change is considered.

Key Words: Taylor Rule, Exchange Rate Determination, Forecast Comparison, Mean Squared Forecast Error, Direction of Change

JEL Classification: F31, E52, C52

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1. Introduction

The challenge of modeling exchange rates is well attested by the difficulty of overturning the well-known Meese and Rogoff (1983a) result. These authors showed that the structural exchange rate models do not outperform a naïve random walk exchange rate specification. Specifically, Meese and Rogoff find that mean squared forecast errors generated from structural exchange rate models are not consistently and significantly smaller than those from a random walk model. It is astonishing, and at times, frustrating that the Meese and Rogoff result has survived largely intact the numerous attempts using different specifications and estimation techniques to beat a random walk. In general, it is hard to find a model that could outperform a random walk exchange rate specification on a consistent basis.[1]

Recently, Engel and West (2005, 2006) explore the implications of monetary policy endogeneity for exchange rate determination. By endogenizing monetary policy and explicitly introducing the interest rate rule, these authors advanced a new and promising approach to model exchange rate behavior. In the context of open economy DSGE model, Benigno (2004), Groen and Matsumoto (2004), Gali (2008) illustrate the effect of monetary policy shocks on exchange rate dynamics.

Indeed the reported performance of exchange rate equations based on interest rate rules is quite positive. For instance, Chinn (2008), Mark (2009), Clarida and Waldman (2008), Molodtsova and Papell (2009), Molodtsova *et al.* (2008), and Wang and Wu (2008) consider various interest rate rule based exchange rate equations, and present favorable findings on their empirical performance that include out-forecasting a random walk.[2]

Most of these studies are based on an empirical or operational interest rate rule from extant empirical monetary policy evaluation studies. At times, the interest rate rules are allowed to have different response coefficients or include a real exchange rate term. A quick review shows that empirical interest rate rules come in different forms and variants for different countries at different historical time periods. When the results based on a particular rule are encouraging, they do not necessarily shed light on the general relevance of the interest rate rule approach.

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[1] See, for example, Cheung *et al.* (2005a, b).
[2] Rogoff and Stavrakeva (2008) express some reservations on the reported superior forecasting results.

A related issue is that the chosen empirical rule may be relevant for empirical policy analysis for a selected data sample, but that rule is not necessarily the "optimal" one in theory. Under a theoretical construct, an optimal interest rule is typically expected to meet the equilibrium determinacy and stability conditions.[3] While policymakers operate in the real world that is far more complicated than a typical theoretical model, an optimal interest rate rule is always a useful benchmark for discussing policy rules. In addition to intellectual curiosity, studies based on optimal interest rate policy rule**s** should complement those based on empirical and operational rules.

In the current exercise, we assess the performance of exchange rate equations derived from both empirical and theoretically optimal interest rate policy rules. As observed by the pioneering work of Meese and Rogoff (1983a) and echoed by Cheung *et al.* (2005b), there is little correspondence between an exchange rate model's in-sample performance and its forecasting ability. This leads to the question, should the assessment be based on in-sample or out-of-sample properties?

One motivation for using out-of-sample forecast performance is to minimize the effect of data mining. It is conceived that researchers tend to report a model that offers the "best" explanatory power. Thus, the reported explanatory power may be spurious and reflect only researchers' conscientious or sub-conscientious search over, say, alternative specifications and sample periods. On the other hand, the out-of-sample forecast exercise subjects a model to the test of real data, and thus, alleviates the data mining effect. However, data mining is not limited to in-sample analyses. Usually, only models performing well in out-of-sample analyses are published. Data mining comes in because, at least in principle, researchers are free to explore different ways to generate forecasts in various sample periods and for different currencies. Indeed, it is not easy to replicate good forecasting performance reported in the literature using different forecasting horizons, forecasting periods, and currencies.

Instead of choosing one of the two, the current study reports both in-sample and out-of-sample results. The in-sample measures include information criteria and R-squares statistics (Inoue and Kilian, 2004, 2006; Clements and Hendry, 2001, 2005). For out-of-sample performance, we follow the Meese and Rogoff tradition and use mean squared forecast errors (MSFEs). In addition, we also consider the direction of change (DOC) statistics.

[3] See, for example, Evans and Honkapohja (2003) on learnability.

In the next section, we briefly discuss the empirical and theoretical interest rate rules used to derive exchange rate equations in our exercise. Specifically, we consider three types of empirical interest rate rules, namely (a) the contemporaneous rule, (b) the backward-looking rule, and (c) the forward-looking rule.

The optimal interest rules are derived from a canonical new Keynesian framework, which is the workhorse of monetary policy analysis. The specification of an optimal rule depends on the model structure, the policy objective, and the assumed adjustment mechanism. In this exercise, we consider optimal interest rate rules constructed under: (a) learning, (b) interest rate inertia, (c) inflation inertia, (d) inflation targeting, and (e) the constant money growth.

We examine the in-sample and out-of-sample performance of exchange rate equations derived from alternative empirical and optimal interest rate rules using the US dollar exchange rate of the British pound, Canadian dollar, Japanese yen, German mark, and Swiss franc. The sample period is 1974:01-2008:12, with the exception of the German mark of 1974:01-1998:12. Our estimation results indicate that these exchange rate equations do not offer substantial explanatory power. The out-of-sample results are a mix. These exchange rate equations do not out-forecast a random walk specification based on the MSFE comparison but they have the ability to correctly predict the direction of exchange rate movement.

In addition, the rolling regression results are used to assess the relative in-sample and out-of-sample performance. It is found that the relative performance of these exchange rate equations varies over time. Further, when an exchange rate equation displays a good in-sample performance, it does not necessarily offer a good forecast.

The remainder of the paper is structured as follows. In the next section we discuss the empirical and optimal interest rate rules and the related exchange rate equations. Section 3 describes the data, estimation methods, and the forecast experience. The in-sample and out-of-sample results are presented in Section 4. Section 5 offers some concluding remarks.

2. Interest Rate Rules and Exchange Rate Dynamics

In his 1993 seminal work, John Taylor showed that the US monetary policy could be characterized by a deterministic rule

$$\tilde{i}_t = \tilde{r} + \pi_t + \beta_\pi(\pi_t - \tilde{\pi}) + \beta_y y_t \,, \quad (1)$$

where $\tilde{i}_t$ is the target short term interest rate, $\tilde{r}$ is the equilibrium real interest rate, π_t and $\tilde{\pi}$ are actual and target inflation rate, respectively, y_t is the output gap. In the 1993 specification, $\tilde{\pi}$ and $\tilde{r}$ are assumed to be 2 percent and the response coefficients β_y and β_π are 0.5. See Taylor (1993) for a detailed discussion of the rule and the related issues. Since then, the Taylor interest rate rule has been modified in various empirical and theoretical studies.

2.1 Empirical Interest Rate Rules and Exchange Rates

Empirical interest rate rules come in different forms and with different explanatory variables. In the subsequent analysis, we consider three representative empirical rules. Readers who are familiar with empirical interest rate rules and are only interested in exchange rate equations implied by these rules could refer to Table 1 and skip this subsection.

2.1.1 Contemporaneous Rule

One common feature of different variants of the interest rate rule is interest rate smoothing. Using the US data Sack (1998) reports significant evidence on interest rate smoothing, which is estimated by the coefficient on the lagged interest rate. Sack and Wieland (2000) review empirical studies and offer various factors that account for interest rate smoothing. Levin *et al.* (1999), Rotemberg and Woodford (1999), and Giannoni and Woodford (2002), on the other hand, discuss the interest-rate smoothing from the theoretical perspective.[4]

To incorporate interest rate smoothing, we follow Clarida *et al.* (1998) and assume the actual interest rate adjusts to the target rate according to

$$i_t = (1-\alpha)\tilde{i}_t + \alpha(L)i_{t-1} + \varepsilon_t, \qquad (2)$$

where $\alpha(L) = \alpha_1 + \alpha_2 L + ...\alpha_n L^{n-1}$, $\alpha \equiv \alpha(1)$, and ε_t is an exogenous random shock to the interest rate, which is i.i.d. In most policy rule estimations, as discussed below in detail, we conclude that the lag length to be n=2. Thus, with interest rate smoothing, the interest rate rule takes the form

$$i_t = (1-\alpha)(\beta_0 + \beta_1\pi_t + \beta_2 y_t) + \alpha_1 i_{t-1} + \alpha_2 i_{t-2} + \varepsilon_t, \qquad (3)$$

[4] Rudebusch (2002, 2006) argues that the significant lagged interest rate is induced by shock persistence rather than monetary policy inertia. Consolo and Favero (2009) also find that the estimated degree of interest rate smoothing is significantly lower than the common value in the empirical literature once controlled for the weak instruments problem in policy rule estimations.

where $\alpha = \alpha_1 + \alpha_2$, $\beta_0 = \tilde{r} - \beta_\pi \tilde{\pi}$, and $\beta_1 = 1 + \beta_\pi$, and $\beta_2 = \beta_y$.

Equation (3) gives a contemporaneous rule in which the monetary policy instrument, i.e. short-term interest rate, reacts to current values of inflation and output gap in addition to the interest rate smoothing terms. Central banks have access to inflation and output data before the public – thus, they could adjust interest rates according to the contemporaneous interest rate rule (3). Benhabib *et al.* (2003), for instance, argue that a policy interest rate rule that responds to past interest rates and current inflation could ensure global stability provided that the interest rate smoothing terms have coefficients that are greater than unity in total.

Assuming that both the home and foreign countries adopt the same interest rate rule with the same coefficients, the interest rate differential is

$$i_t - i_t^* = (1-\alpha)\left[\beta_0 + \beta_1(\pi_t - \pi_t^*) + \beta_2(y_t - y_t^*)\right]$$
$$+\alpha_1(i_{t-1} - i_{t-1}^*) + \alpha_2(i_{t-2} - i_{t-2}^*) + \varepsilon_t, \tag{4}$$

where the foreign variables are indicated by "*". The exchange rate equation under uncovered interest parity $i_t - i_t^* = E_t \Delta s_{t+1}$ is

$$E_t \Delta s_{t+1} = (1-\alpha)\left[\beta_0 + \beta_1(\pi_t - \pi_t^*) + \beta_2(y_t - y_t^*)\right]$$
$$+\alpha_1(i_{t-1} - i_{t-1}^*) + \alpha_2(i_{t-2} - i_{t-2}^*) + \varepsilon_t, \tag{5}$$

where s_t is the log nominal exchange rate expressed as units of domestic currency per one unit of foreign currency. Equation (5) gives the exchange rate equation under the homogenous coefficient assumption. We use the notation "E1" to denote the empirical specification based on the contemporaneous rule (3).

If we relax the assumption and allow the domestic and foreign authorities to adjust the interest rate differently in response to inflation and output, then the exchange rate will respond differently to domestic and foreign shocks. Under the heterogeneous coefficient assumption, the response coefficients of the interest rate rules could be different and the resulting exchange rate equation is

$$E_t \Delta s_{t+1} = \omega + (1-\alpha)(\beta_1 \pi_t + \beta_2 y_t) + \alpha_1 i_{t-1} + \alpha_2 i_{t-2}$$
$$-(1-\alpha^f)(\beta_1^f \pi_t^* + \beta_2^f y_t^*) - \alpha_1^f i_{t-1}^* - \alpha_2^f i_{t-2}^* + \varepsilon_t, \tag{6}$$

where ω is the composite intercept term and the coefficients of the foreign country interest rate rule are indicated by the superscript "*f*".

By incorporating interest rate setting behavior, equations (5) and (6) highlight the role of central bank preferences in determining exchange rates. One striking difference between exchange rate equations derived from the interest rule approach and the standard monetary framework is the absence of money variables in (5) and (6). By endogenizing monetary policy, the interest rule approach does not directly link exchange rate dynamics to money.

Under the homogenous coefficient assumption, both domestic and foreign monetary authorities set their interest rates the same way. The resulting exchange rate responds symmetrically to variations in domestic and foreign determinants. On the other hand, the strong assumption that the domestic and foreign monetary authorities have identical reactions to inflation, output gap, and lagged interest rates is relaxed under the heterogeneous coefficient setting. In this case, exchange rates could respond differently to domestic and foreign variables.

2.1.2 Backward-Looking Rule

The time structure built into the interest rate rule is subject of extensive investigation. One concern is related to inflation indeterminacy and sunspot multiple equilibria. To ensure determinacy and enhance stability, Carlstrom and Fuerst (2000), for example, advocate the adoption of a backward-looking interest rate rule which responds aggressively to past inflation rates. The intuition is that linking interest rates to future inflation forecasts could lead to aggregate fluctuations triggered by self-fulfilling expectations. Benhabib *et al.* (2003) and Eusepi (2005, 2007) present the stabilizing property of a backward-looking interest rate rule, which could be specified as

$$i_t = (1-\alpha)(\beta_0 + \beta_1\pi_{t-1} + \beta_2 y_{t-1}) + \alpha_1 i_{t-1} + \alpha_2 i_{t-2} + \varepsilon_t\,. \tag{7}$$

The exchange rate equations under the homogenous and heterogeneous coefficient assumptions, respectively, are given by

$$\begin{aligned} E_t\Delta s_{t+1} &= (1-\alpha)\big[\beta_0 + \beta_1(\pi_{t-1} - \pi^*_{t-1}) + \beta_2(y_{t-1} - y^*_{t-1})\big] \\ &\quad + \alpha_1(i_{t-1} - i^*_{t-1}) + \alpha_2(i_{t-2} - i^*_{t-2}) + \varepsilon_t\,, \end{aligned} \tag{8}$$

and

$$E_t\Delta s_{t+1} = \omega + (1-\alpha)(\beta_1\pi_{t-1} + \beta_2 y_{t-1}) + \alpha_1 i_{t-1} + \alpha_2 i_{t-2}$$

$$-(1-\alpha^f)(\beta_1^f \pi_{t-1}^* + \beta_2^f y_{t-1}^*) - \alpha_1^f i_{t-1}^* - \alpha_2^f i_{t-2}^* + \varepsilon_t \,. \qquad (9)$$

The empirical specification based on the backward-looking rule will be labeled "E2".

2.1.3 Forward-Looking Rule

Instead of a backward-looking rule, Bernanke and Woodford (1997), Clarida *et al.* (1998), Batini and Haldane (1999) argue that central banks should respond aggressively to expected inflation to avoid real indeterminacy. Countries adopting the inflation targeting policy, including Canada, New Zealand, and the UK, are perceived to contemplate their interest rate policies based on inflation forecasts. The empirical relevancy of forward-looking rules is presented in Clarida *et al.* (1998). In the subsequent analysis, we consider the following empirical forward-looking interest rate rule

$$i_t = (1-\alpha)(\beta_0 + \beta_1 E\pi_{t+12} + \beta_2 y_t) + \alpha_1 i_{t-1} + \alpha_2 i_{t-2} + \epsilon_t \,, \qquad (10)$$

and label the related exchange rate specifications by "E3".

The exchange rate equations under the homogenous and heterogeneous coefficient assumptions, respectively, are given by

$$E_t \Delta s_{t+1} = (1-\alpha)\left[\beta_0 + \beta_1(\pi_{t+12} - \pi_{t+12}^*) + \beta_2(y_t - y_t^*)\right]$$
$$+\alpha_1(i_{t-1} - i_{t-1}^*) + \alpha_2(i_{t-2} - i_{t-2}^*) + \varepsilon_t \,, \qquad (11)$$

and

$$E_t \Delta s_{t+1} = \omega + (1-\alpha)(\beta_1 \pi_{t+12} + \beta_2 y_t) + \alpha_1 i_{t-1} + \alpha_2 i_{t-2}$$
$$-(1-\alpha^f)(\beta_1^f \pi_{t+12}^* + \beta_2^f y_t^*) - \alpha_1^f i_{t-1}^* - \alpha_2^f i_{t-2}^* + \varepsilon_t \,. \qquad (12)$$

For easy reference, we collect these exchange rate equations in Table 1.

The three types of interest rate rules give three different exchange rate formulations. These exchange rate equations embody the complications and theoretical arguments underlying the different interest rate rules. The relevant question is whether the central bank should react to lag, current, or future economic conditions. These are important questions for both academic and practical monetary policy reasons. Apparently, the verdict is still out. In this study, however, our focus is not on the relevance of alternative interest rate rules but on comparing the performance of the implied exchange rate equations.

The three types of exchange rate dynamics may reflect market's perceptions about the central bank behaviors. For instance, the exchange rate might respond strongly to any surprises to inflation or output gap if market players perceive that central banks adjust interest rates contemporaneously. The backward looking rule might be relevant for policy evaluation and yield exchange rate dynamics that is in accordance with the adaptive expectations approach, though its relevance is under debate. The exchange rate equation under forward looking rule, on the other hand, is consistent with the forward looking asset model approach to exchange rate determination. Under the standard forward looking rule, future inflation expectations affect the contemporaneous interest rate, and hence the exchange rate.

2.2 Optimal Rules and Exchange Rate Dynamics

The literature on optimal rule design is voluminous. The formulation of an optimal interest rule depends on, among other things, the structure of the economy under consideration, the central bank's objective function, and the assumption about the adjustment mechanism. In the following, we consider a few optimal interest rate rules derived from a canonical Keynesian macroeconomic framework, which is commonly used in monetary policy literature. The rules have the desirable properties of equilibrium determinacy, stability and learnability (Evans and Honkapohja, 2003). Specifically, these optimal interest rate rules are derived under (a) learnability condition, (b) interest rate inertia assumption, (c) inflation inertia assumption, (d) strict inflation targeting, and (e) constant money growth condition. Further, we consider optimal rules derived under commitment – that is, the rules that incorporate trade-offs across all possible future scenarios.[5]

To conserve space, the derivations of these optimal interest rate rules are presented in the Appendix A1. Again, the exchange rate equation follows from the interest rate rule and the uncovered interest parity. The implied exchange rate equations with the homogenous and heterogeneous interest rate rule assumptions are presented in Table 2. The response coefficients of the optimal interest rate rules and, hence, the coefficients of the implied exchange rate equations are functions of the structural parameters of the underlying objective function and macroeconomic model.

[5] Theoretically, the optimal rule under commitment should yield an equilibrium that is superior in terms of welfare. Also, with commitment policy, the central bank could enhance monetary policy credibility and affect the private sector's inflation expectations (Clarida *et al.*, 1999; Walsh, 2003).

To facilitate discussion, we label "T1" the exchange rate equations based on the optimal rule incorporating learning, "T2" those based on the optimal rule incorporating interest rate inertia, "T3" those based on the optimal rule incorporating inflation inertia, "T4" those based on the optimal rule under strict inflation targeting, and "T5" those based on the optimal rule under constant money growth.

2.3 Discussion

In the previous subsections, we introduced exchange rate equations implied by empirical and theoretically optimal interest rate rules. In the monetary policy literature, different studies consider different empirical and theoretically optimal interest rate rules. There is no consensus on which is the most appropriate empirical or theoretical formulation. The empirical rule could change across countries or historical time periods. The theoretically optimal rule, on the other hand, varies with changes in the model structure and policy preferences. Further, it is known that the optimal interest rate rule could be different from the rules estimated from empirical data, or used in empirical studies.

We note that some studies introduced an exchange rate variable to the interest rate equation to capture the possible policy response to exchange rate variability. The exchange rate variable could take different forms –the change in the nominal, real, effective, or real effective exchange rate, or the deviation from the nominal, real, effective, or real effective equilibrium exchange rate. Taylor (2001), for example, expresses some skepticism on such a modification because the original rule already allows for exchange rate reaction via responding to both inflation and output variations.[6] Recently, Engel (2009) shows that, even for a policy target that includes currency misalignments, the interest rate instrument that responds to the CPI inflation rate could support the policy. In our pilot study, we found that the real exchange rate term was usually insignificant. Thus, we did not include an exchange rate in the interest rate rule in the previous subsections.

In sum, an interest rule based exchange rate equation depends on how the interest rate rule is defined. The performance of the implied exchange rate equation and the relevancy of the

[6] Batini *et al.* (2003) and Leitemo and Söderström (2005), for instance, show that including the exchange rate in policy rule may not improve welfare. The evidence on the empirical relevance of the exchange rate variable is mixed and could be country- and time-period- specific. See, for example, references cited in Taylor (2001), Clarida *et al*. (1998) and Mark (2009).

policy rule based approach could depend on which empirical or theoretically optimal interest rate rule is under consideration. Without knowing which rule is the appropriate one, a study based on some representative interest rate rules is deemed informative.

While the empirical and optimal rules share some similarities, they have different bases. In our comparison, we treat two groups of implied exchange rate equations; those in Table 1 and those in Table 2, separately.

3. Data and Methodology

In this study, we consider the US dollar exchange rates of the British pound, Canadian dollar, Japanese yen, German mark, and Swiss franc. The sample period is 1974:01-2008:12, with the exception of German's sample period of 1974:01-1998:12. The data on exchange rates, money market rates, consumer price indexes, industrial production indexes, and money supplies are drawn from IMF and OECD databases. Inflation is given by the year-over-year change in log consumer price indexes. Output gap is the difference between the industrial production index (in logs) and the index's trend, which is obtained using the Hodrick-Prescott filter with lambda equals to 14400. Appendix A2 gives additional information on the data description and sources.

The in-sample performance is first assessed using the 1974:01-1983:12 sample period. The sample 1984:01-2008:12 is reserved for the subsequent in-sample and out-of-sample performance analysis.

Depending on their functional forms, the empirical- and optimal-rule-based exchange rate equations are estimated by ordinary least squares (OLS), non-linear least squares (NLLS), and general methods of moments (GMM) procedures. For the GMM estimation, we follow Clarida *et al.* (1998) and use the lags of the interest rates, inflation, output gap, and money supply growth as instruments. In the estimation and forecasting exercises, the actual realizations of regressors are used in place of the expectations variables, the contemporaneous and future variables. The approach will alleviate the uncertainty about the values of these regressors on model performance (Meese and Rogoff, 1983a, 1983b).

We consider different metrics for in-sample and out-of-sample comparisons. For in-sample comparison, we use the Akaike Information Criterion (AIC) and the Schwartz Bayesian Criterion (SBC) in addition to the usual adjusted R-squares measure (Inoue and Kilian, 2004).

To evaluate the out-of-sample performance, we adopt the rolling regression approach to generate the MSFE and DOC statistics, and use the random walk benchmark (Meese and Rogoff, 1983a, 1983b).

Specifically, for each exchange rate equation, the first set of parameter estimates are obtained from the initial 1974:01-1983:12 sample period; that is, from the first 120 data points. The estimated equation is used to generate the one-period-ahead forecast. Then the sample is ‘‘rolled’’ forward by dropping the first data point and adding an additional one at the end of the initial sample period. The estimation and forecasting procedures are repeated. The rolling procedure is repeated until all the out-of-sample observations from 1984:01-2008:12 are exhausted. In the case of German mark, the forecast sample ends at 1998:12. For each step of the rolling regression procedure, we record both in-sample and out-of-sample performance measures.

4. In-Sample and Out-of-Sample Performance Analyses

This section presents the estimation results for assessing the in-sample and out-of-sample performance. First we focus on results pertaining to the exchange rate equations based on empirical interest rate rules. Then we discuss the results from the exchange rate equations derived from theoretically optimal interest rate rules. In each case, we compare the estimation results from the initial sample. Then we summarize the in-sample and out-of-sample performance measures from rolling regression. The forecast performance against the random walk benchmark is evaluated using the MSFE and the direction of change statistics (Diebold and Mariano, 1995; Rogoff and Stavrakeva, 2008).

4.1 Exchange Rate Equations Based on Empirical Interest Rate Rules

4.1.1 Homogenous Specification

In Table 3, we report the results of estimating the exchange rate equations based on empirical interest rate rules that have the same reaction coefficients for the domestic and foreign countries. The estimation period is 1974:01-1983:12; roughly the first decade of the free-floating exchange rate regime. This period partially overlaps with the sample period in Meese and Rogoff (1983a).

In general, the adjusted R-square estimates are small and, thus, are indicative of the limited explanatory power of these exchange rate equations. The result is in accordance with the difficulty of estimating exchange rates using fundamentals reported in literature. The inflation and output gap differential effects revealed by the β_1 and β_2 estimates display different signs across currencies and exchange rate equations. It is noted that these estimates have a positive sign in theory. Thus, the empirical estimates do not lend strong support on the effects of inflation and output gap differentials on exchange rate changes.

While it is encouraging to observe that the statistically significant β_1 and β_2 estimates are all positive, there are only two significant β_1 estimates and two significant β_2 estimates. Interestingly, three of the four significant estimates are generated under E3, the exchange rate equation based on the forward looking interest rate rule given by equation (11).

One of the characteristics of the empirical interest rate rule is interest rate smoothing, which is captured by α_1 and α_2, the coefficients of lagged interest rates. These interest rate smoothing parameters are incorporated in the exchange rate equations through an uncovered interest parity. The α_1 and α_2 estimates in Table 3, however, are quite small in magnitude and do not indicate substantial interest rate persistence. In fact, these estimates do not have the same sign across currencies and are statistically significant for only a handful of cases. For Switzerland, the α_1 estimate is significantly negative under specifications E1 and E2 – the exchange rate equations are based on the contemporaneous and backward looking interest rate rules given by equations (5) and (8). The other case of a significant interest rate smoothing is observed for Canada - α_2 estimate is significantly positive under all three selection exchange rate equations. Apparently, the results do not support a strong and consistent interest rate smoothing effect in these exchange rate specifications.

In passing, we note that when we estimated the empirical interest rate rules (3), (7), and (10), the α_1 and α_2 estimates are large and significantly positive. The results are in accordance with the usual interest rate smoothing behavior reported in studies estimating policy rules. The uncovered interest parity that links interest rate rules and exchange rate equations seems to be the culprit of differences in the α_1 and α_2 estimates from the empirical interest rate rules and their implied exchange rate equations. The use of uncovered interest parity is not uncontroversial. The empirical relevancy of the parity condition is frequently challenged by the so-called forward premium puzzle, which suggests that the exchange rate changes are negatively, instead of positively, related to interest rate differentials.[7] The results in Table 3, nonetheless, offer no consistent evidence for either a *significant* positive or negative interest rate effect.

As noted earlier, the in-sample performance as gauged by the adjusted R-square estimates is quite weak. It is notoriously difficult to explain exchange rates using fundamentals; especially at high frequency like monthly data. The low adjusted R-square estimates attest to the apparent disconnect between exchange rates and their fundamentals. In most cases, parameter estimates are statistically insignificant and could have signs different from their theoretical values.

The rankings based on AIC are listed near the bottom of Table 3. The rankings based on SBC and adjusted R-square estimates are similar to those reported. According to both information criteria, the preferred model is either the one based on the backward looking rule (E2) or the forward looking (E3) rule.

Table 4 presents the in-sample and out-of-sample performance measures obtained from the rolling regression scheme described in Section 3. The in-sample AIC, SBC and R-square estimates and the out-of-sample one-step ahead squared forecast errors are summarized. Specifically, for each currency and each exchange rate equation, the means of individual measures are given under the column labeled "M," the column "R" gives a model's rankings based on the average values of the measures listed in the first column, and the column "F" gives the frequencies at which a model is selected as the best one among the three exchange rate specifications during the rolling regression exercise.

For each currency under consideration, the average in-sample performance measures; that is, the AIC, SBC and R-square estimates, tend to select the same model specification. In the case of the British pound, for example, the three measures favor the E1 specification; that is the exchange rate equation based on the contemporaneous interest rate rule. The selected model specification, nonetheless, varies across currencies. These selected models are quite different from those selected from the initial sample of the rolling regression in Table 3. Indeed, only the Canadian dollar has the same specification – the model based on the backward looking rule – ranked number one in both tables.

The numbers reported under the column "F" show that the ranking of these models could switch during the rolling regression exercise. That is, the relative explanatory power of these

[7] Molodtsova and Papell (2009) and Chinn (2008), for example, imposed a negative interest rate (and, hence, a negative inflation) effect on their policy rule based exchange rate equations.

models is not constant during the forecast period of 1984:01 to 2008:12. In the case of British pound, the average AIC selects model E1, which is ranked the best 60% of the time. However, in the case of Swiss franc, the average AIC selects model E1, which is ranked the best only 25% of the time. In checking through the individual AIC estimates, it is found that when the model E1 is ranked number 1, it is "much" better than the alternative; when it is not selected, it is only slightly worse. Thus, the average AIC is better than others. Therefore, the relative in-sample performance of these models could vary quite substantially across rolling samples and currencies.

The rankings based on the one-step ahead mean squared forecast errors (MSFEs) are not all the same as those based on the three in-sample performance measures. In three cases under consideration, the model ranked the best by MSFEs is different from the one ranked the first by, say, the average AIC. That is the model that gives the smallest MSFE may not have the best average AIC value. There is a discrepancy between the one-step ahead forecast performance and the in-sample performance. It is of interest to note that the MSFE criterion selects model E2, which is based on the backward looking rule, for three of the five currencies.

In sum, the results in Tables 3 and 4 show that none of the three exchange rate equations is consistently better than other two throughout the rolling sample periods across all the selected performance measures.

4.1.2 Heterogeneous Specification

In Table 5, we report estimation results from heterogeneous models. Arguably, different central banks could assign different response coefficients for their interest rate policies. To allow for different reaction functions, we estimate the exchange rate equations based on empirical interest rate rules with heterogeneous coefficients. The set of parameters (β_1, β_2, α_1, α_2) is for the home country, while the second set of parameter (β_1^f, β_2^f, α_1^f, α_2^f) is for the foreign country, in this case the US.

The inflation effect is mainly found in the UK data. The β_1 and β_1^f estimates under the BP/$ heading are significant and with the expected signs. The β_2 and β_2^f estimates that capture the output effect are only significant in two BP/$ cases. The two significant cases, however, display negative output effect that is opposite to the predicted positive sign. Similar to the homogenous coefficient results in Table 3, the α_1, α_2, α_1^f, and α_2^f do not offer serious evidence on interest rate smoothing behavior even though the smoothing behavior is quite commonly found in estimating individual interest rate rules. Somehow the smoothing behavior pertaining to the interest rate rule dissipates in the exchange rate equations.

According to the adjusted R-square estimates, the BP/$ and DM/$ models with interest rate rules that allow for heterogeneous coefficients have an explanatory power better than the corresponding models with homogenous coefficients. The CAN$/$ model, however, gives the opposite results. For the remaining two cases, the relative explanatory power depends on the underlying interest rate rule. Thus, allowing the home and foreign countries to have different response coefficients does not always improve the in-sample performance.

Among E1, E2 and, E3, the information criteria tend to favor the model derived from the backward-looking rule E2, which is ranked first in three out of five cases.

Table 6 summaries the in-sample and out-of-sample performance statistics compiled from the rolling regression exercise. Similar to the cases with homogenous coefficients, for each currency, the in-sample AIC, SBC and R-square measures give same rankings for alternative specifications. Compared with Table 4, the MSFE rankings in Table 6 are slightly more in line with the in-sample measure rankings. However, there are still two of the five cases in which the specification that gives the smallest MSFE is not the one that yields the best average in-sample performance. Again, these in-sample and out-of-sample measures do not offer strong evidence that any one of the three specifications consistently outperform others. The results on the different in-sample and out-of-sample performance rankings and the spread of first ranked specification are similar to those observed in Table 4.

4.1.3 Forecast Evaluation

In the previous subsections, it is observed that the forecast ability of these models could differ from their in-sample performance and be worse than the simple random walk hypothesis. Here, we provide additional statistical evidence on these two observations.

Table 7 assesses the association between in-sample and out-of sample performance. For each currency, we ranked individual exchange rate equations based on the MSFE and AIC criteria at each round of the rolling regression exercise. Then, we calculated the correlation coefficient of the two series of MSFE and AIC ranks. The use of rank correlations alleviates the implication of the distributions of these performance measures on the inference. The rank correlation estimates in the table are small (in absolute value) and mostly statistically insignificant. The occurrence of negative rank correlations slightly outnumbers the positive rank correlations. The positive and negative rank correlations are quite evenly distributed across the homogenous and heterogeneous specifications. Among the three cases that the rank correlation estimates are significant at the 10% level, two have a negative sign. The evidence, thus, is weakly suggestive that the out-of-sample performance is disconnected with the in-sample performance. Indeed, a specification that has a good in-sample performance according to AIC tends to give a not-so-good forecasting result.

Table 8 evaluates the out-of-sample forecast performance using the Diebold and Mariano (1995) test statistic. The focus is on the MSFE and the ability to predict the direction of change. Individual exchange rate equations are compared again a random walk model, which is common benchmark model used in the exchange rate forecasting exercises.

For MSFE, we compare the equation's one-step ahead forecast errors to the random walk specification. The null hypothesis of no difference in forecasting accuracy is rejected in favor of the exchange rate equation (random walk specification) if the Diebold and Mariano test statistic is negative (positive) and statistically significant. These statistics and their statistical significance based on bootstrapping distributions are reported under the heading "MSFE."

The MSFE differentials do not offer any evidence that these exchange rate equations yield better one-step ahead forecasts than the random walk model. Most of the differentials and hence the statistics are positive; indicating that the forecast errors are usually more volatile than the observed changes in exchange rates. Indeed, some of these positive Diebold and Mariano test statistics are statistically significant based on bootstrapped critical values. For some limited cases, we obtained negative but insignificant Diebold and Mariano test statistics. Thus, while there are some cases in which the random walk out-forecasts an exchange rate equation, there is no statistically significant evidence that any of these exchange rate equations out-forecast the random walk specification.

In addition to the metric based on mean squared forecast errors, we assess the forecasting ability using the DOC criterion. In essence, the DOC focuses on the ability to forecast the exchange rate's direction of change. The DOC statistic is based on the normalized ratio of the number of forecasts that correctly predict the direction of exchange rate movement to the total number of forecasts. If the ratio is statistically larger than ½, then the corresponding exchange rate equation contains useful information about exchange rate movements. We implicitly assume that a random walk specification assign a probability of ½ for either an upward or a downward movement. The DOC statistics calculated according to Diebold and Mariano (1996) and their significance are presented under the columns labeled "DOC."

While these exchange rate equations yield forecasts that are more volatile than the random walk specification, they tend to do well in predicting the direction of movement. The DOCs are all positive and most of them are statistically significant. That is, more than one half of these forecasts correctly predict the exchange rate movement. The direction forecast ability is significant in the statistical sense and is not likely to be spurious. The exchange rate equations based on heterogeneous interest rate rules garner more significant DOC statistics than those based on homogeneous interest rate rules and, thus, display a stronger direction forecast ability.

4.2 Optimal Rule Results

In this subsection, we examine the in-sample and out-of sample performance of exchange rate equations based on policy interest rate rules that are derived from a canonical macroeconomic model. As in the previous subsection, we present results from specifications that allow for homogeneous and heterogeneous interest rate response coefficients.

Table 9 and Table 10 report the in-sample estimation results for exchange rate equations derived from homogeneous and heterogeneous interest rate rules. These results are quite compared to those based on empirical interest rate rules (Tables 3 and 5) in the sense that the in-sample fit is weak as indicated by the adjusted-square estimates. The estimated inflation effect, output effect, and smoothing behavior vary across currencies and are quite different from their predicted values. There is some evidence that that the equation fits slightly better when the home and foreign coefficients were not constrained to be the same – however, the improvement is not uniform across currencies and specifications. Further, according to adjusted-square estimates, there specifications are not necessarily better than those based on empirical interest rate rules.

In Table 9, the AIC selects T4 – the exchange rate specification under inflation targeting, as the best model for two currencies, the Canadian dollar and Japanese yen. For those with heterogeneous response coefficients in Table 10, the AIC selects the specification T1 that allows for learning as the best model for three currencies; the British pound, Swiss franc and German mark. In total, model T1 is chosen as the best model in 4 out of 10 cases in Tables 9 and 10.

The in-sample and out-of-sample performance measures for models with homogeneous and heterogeneous response coefficients obtained from the rolling regression exercise are presented in Tables 11 and 12. Compared with results in Tables 4 and 6, the average in-sample performance measures in Tables 11 and 12 do not necessarily select the same equation specification. There are only two cases each in these two Tables that the three in-sample measures – AIC, SBC and R-square estimate – selected the same specification. On the rankings based on the in-sample and out-sample performance measures, there are several cases in which the average MSFE and at least one of the average in-sample measures select the same specification. It is hard to assert these results represent a strong link between in-sample and out-of-sample performance since these in-sample measures could select different specifications.

In Table 13, the rank correlation estimates show that, compared with the results in Table 7, the AIC and MSFE performance measures display a stronger degree of association. There are 10 significant rank correlation estimates. However, only three of them are positive and the other seven are negative. Thus, the significance does not mean that a model's in-sample performance is necessarily aligned with its out-of-sample performance.

The forecasting performance of these exchange rate equations relative to the random walk specification presented in Table 14 is qualitatively similar to the results in Table 8 for those derived from empirical interest rate rules. Specifically, the MSFE criterion suggests that these exchange rate equations do not out-forecast a random walk model. There are cases where a random walk model is significantly better than the exchange rate equation, but there is not a case where an exchange rate equation is better.

The DOC statistic, on the other hand, suggests these exchange rate equations predict the exchange rate movement quite well. All these statistics indicate the exchange rate equation forecasts correctly predict the direction more than half of the cases. Indeed, 11 cases for models with homogeneous coefficients and 17 cases for models with heterogeneous coefficients have statistically significant DOC statistics – indicating significant direction prediction power. It is interesting to note that none of the DOC statistics are significant for the Japanese yen.

5. Conclusions

In this paper, we examine the performance of exchange rate equations that are derived from empirical and theoretically optimal interest rate rules. The domestic and foreign interest rate rules may have the same or different response coefficients. The US dollar exchange rates of the British pound, Canadian dollar, Japanese yen, German mark, and Swiss franc are considered. The sample period is from 1974:01 to 2008:12; with the exception of the German sample period from 1974:01 to 1998:12. Results from rolling regressions are used to assess in-sample and out-of-sample performance.

The estimation results suggest that these exchange rate equations have limited in-sample explanatory power. There is no strong evidence that a specific exchange rate equation based on either theoretically optimal or empirical interest rate rules offers a consistently better explanatory power than other specifications across all the five currencies under consideration. Further, the relative explanatory power of these models varies over time.

The relative rankings of these models' forecast performance as measured by their MSFEs change over time. There is no one model that consistently outperforms others over time and across currencies. Further, the correlation between a model's ranks based on MSFE and AIC is quite weak. There is little association between an exchange rate equation's explanatory power and its forecast ability – an equation that offers better in-sample performance does not necessarily have good forecast ability.

The comparison of the forecast performance between these exchange rate equations and a random walk offers some mixed evidence. The MSFEs of these exchange rate equations are usually not smaller than the random walk specification. The Diebold-Mariano test affirms that the random walk model is not out-performed in term of MSFEs. Instead, the test results point to the possibility that these exchange rate equations offer forecasts than are worse than the random walk model. The DOC statistic, on the other hand, suggests that these exchange rate equations have ability to predict the direction of exchange rate variations. Most exchange rate equations correctly predict the exchange rate's direction of change in a statistically significant manner.

To shed some light on the change in forecast ability of alternative exchange rate equations, we reported the forecast error for empirical and optimal rule based exchange rate equation in Graph 1 and 2, respectively. The forecast errors obtained from exchange rate equations based on homogenous coefficients for both empirical and optimal rules do not display any consistent pattern across currencies and data sample. For instance, forecast errors from empirical rule based equations increase for Canada after early 2000s while there is a decline for the UK and Switzerland, if the recent observations are excluded. Thus, we are not able to make any assessment on whether the forecasting power of these equations has improved over time.

Three countries in our sample; namely Canada, the U.K. and Switzerland, adopted the inflation targeting policy at different points of time throughout the 1990s. The switch to inflation targeting may affect the implementation of interest rate rules, the corresponding implied exchange rate equations, and hence the exchange rate behavior. Therefore, for these countries, we repeated the exercise and assessed the in-sample and out-of-sample performance using data from the respective pre- and post-inflation targeting periods. The in-sample performance, out-of-sample performance, and their degree of association are qualitatively the same as those reported in Section 4. These results are available upon request.

In sum, our exercise offers very limited evidence on the ability of interest rate rule based exchange rate equations to explain exchange rate behavior or to forecast exchange rates according to the commonly used MSFE criterion. While these results do not preclude a specific interest rate rule based exchange rate equation to offer good explanatory and forecasting results in a specific setting, they allude to the generality of using interest rate rule based exchange rate equations to model exchange rate behavior.

Appendix A1: Optimal Interest Rate Rules

The optimal rules in this study are based on the canonical New Keynesian model that includes an expectations-augmented Phillips curve and a forward-looking IS curve. The model could be written as (Clarida *et al.*, 1999):

$$\text{Phillips curve: } \pi_t = \beta E_t \pi_{t+1} + \kappa y_t + e_t,$$

$$\text{IS curve: } y_t = E_t y_{t+1} - \varphi\left[i_t - E_t \pi_{t+1}\right] + u_t,$$

where π_t is inflation rate, y_t is the output gap given by the deviation of the actual output from its natural level in logs, i_t is the nominal interest rate, and E_t is the expectations operator. The parameters κ and φ are assumed to be positive. β is the discount factor between zero and one. The cost push shock is given by e_t and u_t is a preference or demand shock.[8]

The policy objective is to minimize the expected discounted sum of the losses given by

$$E_o\left[\Sigma_{j=0}^{\infty} \beta^j L_t\right],$$

where the loss function relevant to the central bank's decision is given by

$$L_t = \pi_t^2 + \lambda y_t^2,$$

in which, λ is the relative weight placed on stabilizing the output gap versus inflation. The loss-function defined here is also known as the *period loss function.* Given the policy objective for the central bank, in general for the monetary policy implementations, the short term interest rates are the policy instruments. Therefore, the optimal interest rate rule can be obtained by minimizing the objective function subject to the structure of economy represented by the IS and Phillips curves.

Another relevant question in monetary policy analysis is whether the optimal rule should be derived under discretion or commitment? Under discretion, the central bank's job is to minimize the loss in the next period, and is not bounded by happenings in any subsequent periods. Under commitment, the central bank has to choose a policy rule (and, hence the implied inflation and output gap paths) which minimizes the intertemporal loss-function. In addition to the theoretical attribute that the optimal rule under commitment should yield an equilibrium that is superior in terms of welfare, it also argued that the central bank could enhance monetary policy credibility and affect the private sector's inflation expectations if it follows commitment rule (Clarida *et al.*, 1999; Walsh, 2003). In current exercise, we only consider the optimal rule under commitment policy, and hence the exchange rate equations based on these rules.

T1- Learning

By substituting the Phillips curve and the IS curve into the *intertemporal loss function*, the objective function of the optimizing exercise can be written as

$$\pounds_t = E_t \Sigma_{j=0}^{\infty} \beta^j \{\tfrac{1}{2}(\pi_{t+j}{}^2 + \lambda y_{t+j}^2) \ + \theta_{t+j}[y_{t+j} - y_{t+j+1} + \varphi(i_{t+j} - \pi_{t+j+1}) - u_{t+j}]$$

[8] If the aim is to find the solutions of π_t and y_t in term of shocks, then it is customary to assume the shocks follow an autoregressive process like $e_t = \rho_e e_{t-1} + \varepsilon_{e,t}$ and $u_t = \rho_u u_{t-1} + \varepsilon_{u,t}$; where $0 \leq \rho_e, \rho_u < 1$, and $\varepsilon_{e,t}$ and $\varepsilon_{u,t}$ are white noises.

$$+\psi_{t+i}[\pi_{t+j} - \beta\pi_{t+j+1} - \kappa y_{t+j} - e_{t+j}]\}.$$

Under commitment, the first order conditions are

$$\varphi E_t(\theta_{t+j}) = 0 \text{ if } j \geq 0,$$

$$\pi_t + \psi_t = 0 \text{ if } j = 0,$$

$$\beta^j E_t(\pi_{t+j} + \psi_{t+j} - \psi_{t+j-1}) - \varphi\beta^{j-1}\theta_{t+j-1} = 0 \text{ if } j \geq 1,$$

$$\lambda y_t + \theta_t - \kappa\psi_t = 0 \text{ if } j = 0,$$

$$\beta^j E_t(\lambda y_{t+j} + \theta_{t+j} - \kappa\psi_{t+j}) + \beta^{j-1}\theta_{t+j-1} = 0 \text{ if } j \geq 1.$$

From the first order condition, the IS curve does not impose any constraint since $\theta_t = 0$. In this case, we have a compact form given by

$$\pi_t + \psi_t = 0 \quad j = 0,$$

$$E_t(\pi_{t+j} + \psi_{t+j} - \psi_{t+j-1}) = 0 \quad j \geq 1,$$

$$E_t(\lambda y_{t+j} - \kappa\psi_{t+j}) = 0 \quad j \geq 0.$$

Suppose the expectations/decision pertaining to the last equation was formed in distant past, which Woodford (1999) calls the "timeless-perspective," we have $\psi_t = \frac{\lambda}{\kappa} y_t$. Therefore, $\pi_t = -\frac{\lambda}{\kappa}(y_t - y_{t-1})$ gives the first order optimal condition. Using the inflation equation, the solution for the output gap (not imposing rational expectations) is

$$y_t = -\frac{\kappa\beta}{\lambda+\kappa^2}\widehat{E}_t\pi_{t+1} + \frac{\lambda}{\lambda+\kappa^2}y_{t-1} - \frac{\kappa}{\lambda+\kappa^2}e.$$

Thus, the rule under commitment can be derived by substituting this equation into the IS curve and be written as

$$i_t = \left(1 + \frac{\kappa}{\varphi(\lambda+\kappa^2)}\right)\beta\widehat{E}_t\pi_{t+1} - \frac{\lambda}{\varphi(\lambda+\kappa^2)}y_{t-1} + \frac{1}{\varphi}\widehat{E}_t y_{t+1} + \frac{1}{\varphi}u_t + \frac{\kappa}{\varphi(\lambda+\kappa^2)}e_t.$$

As shown in Table 2, we rewrite the rule under learning in estimating equation as in the following form;

$$i_t = \beta_0 + \beta_1\widehat{E}_t\pi_{t+1} + \beta_2\widehat{E}_t y_{t+1} + \beta_3 y_{t-1} + \varepsilon_t,$$

where the response coefficients are given by $\beta_1 = 1 + \kappa\beta / [\varphi(\lambda + \kappa^2)]$, $\beta_2 = 1 / \varphi$, $\beta_3 = -\lambda / [\varphi(\lambda + \kappa^2)]$, and ε_t, is given by $\varepsilon_t = u_t / \varphi + \kappa e_t / \varphi(\lambda + \kappa^2)$.[9]

The exchange rate equations based on the optimal rule under learning with homogenous and heterogeneous coefficients can be written as

$$E_t\Delta s_{t+1} = \beta_0 + \beta_1\widehat{E}_t(\pi_{t+1} - \pi^*_{t+1}) + \beta_2\widehat{E}_t(y_{t+1} - y^*_{t+1}) + \beta_3(y_{t-1} - y^*_{t-1}) + \varepsilon_t$$

and

[9] Note that we add intercept term β_0 to the estimating equation corresponding to satisfy standard assumptions.

$$E_t\Delta s_{t+1} = \beta_0 + \beta_1 \widehat{E}_t\pi_{t+1} + \beta_2 \widehat{E}_t y_{t+1} + \beta_3 y_{t-1} - (\beta_1^f \widehat{E}_t\pi_{t+1}^* + \beta_2^f \widehat{E}_t y_{t+1}^* + \beta_3^f y_{t-1}^*) + \varepsilon_t.$$

T2-Interest Rate Inertia

The solution for the optimal interest rate rule under including interest rate inertia can be found in Giannoni and Woodford (2002, 2003) and Woodford (2003). Here we only provide the optimization problem under optimal commitment, and the resulting rule. Given the *intertemporal loss function* for the model with interest rate inertia, the Phillips curve, and the IS curve, the objective function of the optimization problem can be written as

$$\pounds_t = \tfrac{1}{2} E_t \Sigma_{j=0}^{\infty} \beta^j \{(\pi_{t+j})^2 + \lambda_y y_{t+j}^2 + \lambda_i (i_{t+j} - \tilde{i})^2 + \theta_{t+j}[y_{t+j} - E_t y_{t+j+1} + \varphi\left[i_{t+j} - E_t \pi_{t+j+1}\right] - u_{t+j}] + \psi_{t+j}[\pi_{t+j} - \beta E_t \pi_{t+j+1} - \kappa y_{t+j} - e_{t+j}]\}.$$

The corresponding rule under commitment is

$$i_t = (1-\rho_1)\tilde{i} + \rho_1 i_{t-1} + \rho_2 \Delta i_{t-1} + \phi_\pi \pi_t + \phi_y \Delta y_t\,,$$

where $\rho_1 = 1 + \kappa\varphi / \beta$, $\rho_2 = 1 / \beta$, $\phi_\pi = \kappa\varphi / \lambda_i$, and $\phi_y = \varphi\lambda_y / \lambda_i$. The corresponding rule for estimating equation is given by

$$i_t = \beta_0 + \alpha_1 i_{t-1} + \alpha_2 \Delta i_{t-1} + \beta_1 \pi_t + \beta_2 \Delta y_t + \varepsilon_t\,,$$

where $\beta_0 = (1-\rho_1)\tilde{i}$, and the other parameters, α's and β's replaces the equivalent ones given in the optimal rule. The corresponding exchange rate equation based on optimal rule under interest rate inertia with homogeneous and heterogeneous coefficients, which are presented in Table 2, could be derived as in case for optimal rule under learning.

T3-Inflation Inertia

For the optimal under inflation inertia, we consider the possibility of partial inflation adjustment as in Giannoni and Woodford (2002) and Woodford (2003). Such adjustment process involve a modification of the Phillips curve, and accordingly the loss function as follows

$$\pi_t - \gamma\pi_{t-1} = \beta E_t(\pi_{t+1} - \gamma\pi_t) + \kappa y_t + e_t,$$

and

$$L_t = (\pi_t - \gamma\pi_{t-1})^2 + \lambda_y y_t^2 + \lambda_i (i_t - \tilde{i})^2,$$

where $\gamma \in (0,1)$ determines the speed of inflation adjustment. Thus, the optimization problem under inflation inertia can be written as

$$\pounds_t = \tfrac{1}{2} E_t \Sigma_{j=0}^{\infty} \beta^j \{(\pi_{t+j} - \gamma\pi_{t+j-1})^2 + \lambda_y y_{t+j}^2 + \lambda_i (i_{t+j} - \tilde{i})^2 + \theta_{t+j}[y_{t+j} - E_t y_{t+j+1} + \varphi(i_{t+j} - E_t \pi_{t+j+1} - u_{t+j}] + \psi_{t+j}[(\pi_{t+j} - \gamma\pi_{t-1+j}) - \beta E_t(\pi_{t+1+j} - \gamma\pi_{t+j}) - \kappa y_{t+j} - e_{t+j}]\}\,.$$

The optimal instrument rule under the commitment with inflation inertia is given by (Giannoni and Woodford, 2002; Woodford, 2003)

$$i_t = (1-\rho_1)\bar{i} + (\phi_\pi - \theta_\pi)\overline{\pi} + \rho_1 i_{t-1} + \rho_2 \Delta i_{t-1} + \phi_\pi F_t(\pi) + \phi_y F_t(y) - \theta_\pi \pi_{t-1} - \theta_y y_{t-1},$$

where $F_t(.)$ denotes a linear combination of forecasts of the argument at various horizons, $\bar{i}$ and $\overline{\pi}$ are the means of inflation and interest rates, $\rho_1 = 1 + (\lambda_2 - 1)(1 - \lambda_1)$, $\rho_2 = \lambda_1\lambda_2$, $\phi_\pi = \theta_\pi\{1 + (1-\gamma)(1-\beta\gamma)/[\gamma(1-\lambda_3^{-1})]\}$, $\theta_\pi = \kappa\varphi / \lambda_i\beta\lambda_3$, and $\phi_y = \theta_y = \lambda_y\varphi / \lambda_i\beta\gamma\lambda_3$. See the Woodford (2003) for the details and definition of the parameters λ_1, λ_2, and λ_3 which are related to adjustments to inflation. The resulting optimal rule for estimating equation is given by

$$i_t = \beta_0 + \alpha_1 i_{t-1} + \alpha_2 \Delta i_{t-1} + \beta_1 F_t(\pi) + \beta_2 F_t(y) - \beta_3\pi_{t-1} - \beta_4 y_{t-1} + \epsilon_t,$$

where $\beta_0 = (1-\rho_1)\bar{i} + (\phi_\pi - \theta_\pi)\overline{\pi}$, and the other parameters refer to the equivalent ones in optimal rule. The corresponding exchange rate equations based on this optimal rule are presented in Table 2, could be derived as in case for optimal rule under learning.

T4-Inflation Targeting

We illustrate the strict inflation targeting case by modifying the intertemporal loss function under interest rate inertia such that the weight on output gap stabilization is zero. Incorporating the Phillips curve and the IS curve into the *intertemporal loss function* gives the optimization problem as follows

$$\begin{aligned} \pounds_t = E_t\Sigma_{j=0}^{\infty}\beta^j\{\tfrac{1}{2}(\pi_{t+j}{}^2 + \lambda_i(i_{t+j} - \tilde{i})^2) \\ +\theta_{t+j}[y_{t+j} - y_{t+j+1} + \varphi(i_{t+j} - \pi_{t+j+1}) - u_{t+j}] \\ +\psi_{t+i}[\pi_{t+j} - \beta\pi_{t+j+1} - \kappa y_{t+j} - e_{t+j}]\}. \end{aligned}$$

From a "timeless perspective" (and for $j \geq 1$), the first order conditions are

$$\pi_t + \psi_t - \psi_{t-1} - \varphi\beta^{-1}\theta_{t-1} = 0,$$

$$\theta_t - \beta^{-1}\theta_{t-1} - \kappa\psi_t = 0,$$

$$\lambda_i(i_t - \tilde{i}) + \theta_t\varphi = 0.$$

The optimal interest rate rule can be obtained by solving for the two Lagrange multipliers, θ_t and ψ_t. Under commitment, thus, the optimal interest rate rule can be expressed as

$$i_t = (1-\rho_1)\tilde{i} + \rho_1 i_{t-1} + \rho_2\Delta i_{t-1} + \phi_\pi\pi_t,$$

where $\rho_1 = 1 + \kappa\varphi / \beta$, $\rho_2 = 1 / \beta$, and $\phi_\pi = \kappa\varphi / \lambda_i$. The corresponding interest rate rule for estimating exchange rate equation is given by

$$i_t = \beta_0 + \alpha_1 i_{t-1} + \alpha_2\Delta i_{t-1} + \beta_1\pi_t + \varepsilon_t,$$

where $\beta_0 = (1-\rho_1)\tilde{i}$, and the other parameters, α's and β's replaces the equivalent ones given in the optimal rule.

T5: Money Growth

Under a constant money growth target, the period loss function can be modified to (Svensson, 1999):

$$L_t = (k_t - \tilde{k})^2,$$

where k_t is the growth rate of money supply, and $\tilde{k}$ is the target growth rate. Assume the money process follows the law of motion

$$m_t = m_{t-1} + k_t + \omega_t,$$

where m_t is the log of money supply and ω_t is the innovation term. The demand for real balances is a function of the output and nominal interest rate, and the money market equilibrium is given by

$$m_t - p_t = \nu \tilde{y}_t - i_t/\eta + \varsigma_t,$$

where p_t is the log price level and $\tilde{y}_t$ is the log nominal output. The interest rate rule which incorporates the money growth rate is given by

$$i_t = i_{t-1} + \eta(\pi_t - k_t) + \nu\eta g_{y,t} + \chi_t,$$

where $\pi_t = p_t - p_{t-1}$, $g_{y,t} = \tilde{y}_t - \tilde{y}_{t-1}$, and $\chi_t = \eta(\varsigma_t - \varsigma_{t-1} - \omega_t)$, and the corresponding rule for estimating exchange rate equation is given by

$$i_t = \beta_0 + \alpha_1 i_{t-1} + \beta_1(\pi_t - k_t) + \beta_2 g_{y,t} + \varepsilon_t.$$

Appendix A2: Data Description and Their Sources

Series	Description	Source
Nominal Exchange Rate	U.S. Dollars per National Currency (end of period)	IFS (line ae).
Interest Rate	Money market rate-monthly average rates of all calendar days	IFS (line 60b)
Money Supply	M1 Stock-seasonally adjusted, and M4 for the UK	OECD Stats and Bank of England for the UK
Consumer Price Index	Covers all cities (or country)	IFS and OECD-MEI for Germany.
Industrial Production Index	Seasonally adjusted monthly series	IFS (line 66c)

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Table 1: Exchange Rate Models Based on Empirical Interest Rate Rules

Homogeneous Specifications

E1: Contemporaneous Rule – $E_t \Delta s_{t+1} = (1-\alpha)\left[\beta_0 + \beta_1(\pi_t - \pi_t^*) + \beta_2(y_t - y_t^*)\right] + \alpha_1(i_{t-1} - i_{t-1}^*) + \alpha_2(i_{t-2} - i_{t-2}^*) + \varepsilon_t$

E2: Backward-Looking Rule – $E_t \Delta s_{t+1} = (1-\alpha)\left[\beta_0 + \beta_1(\pi_{t-1} - \pi_{t-1}^*) + \beta_2(y_{t-1} - y_{t-1}^*)\right] + \alpha_1(i_{t-1} - i_{t-1}^*) + \alpha_2(i_{t-2} - i_{t-2}^*) + \varepsilon_t$

E3: Forward-Looking Rule – $E_t \Delta s_{t+1} = (1-\alpha)\left[\beta_0 + \beta_1(\pi_{t+12} - \pi_{t+12}^*) + \beta_2(y_t - y_t^*)\right] + \alpha_1(i_{t-1} - i_{t-1}^*) + \alpha_2(i_{t-2} - i_{t-2}^*) + \varepsilon_t$

Heterogeneous Specifications

E1: Contemporaneous Rule – $E_t \Delta s_{t+1} = \omega + (1-\alpha)(\beta_1 \pi_t + \beta_2 y_t) + \alpha_1 i_{t-1} + \alpha_2 i_{t-2}$

$$-(1-\alpha^f)(\beta_1^f \pi_t^* + \beta_2^f y_t^*) - \alpha_1^f i_{t-1}^* - \alpha_2^f i_{t-2}^* + \varepsilon_t$$

E2: Backward-Looking Rule – $E_t \Delta s_{t+1} = \omega + (1-\alpha)(\beta_1 \pi_{t-1} + \beta_2 y_{t-1}) + \alpha_1 i_{t-1} + \alpha_2 i_{t-2}$

$$-(1-\alpha^f)(\beta_1^f \pi_{t-1}^* + \beta_2^f y_{t-1}^*) - \alpha_1^f i_{t-1}^* - \alpha_2^f i_{t-2}^* + \varepsilon_t$$

E3: Forward-Looking Rule – $E_t \Delta s_{t+1} = \omega + (1-\alpha)(\beta_1 \pi_{t+12} + \beta_2 y_t) + \alpha_1 i_{t-1} + \alpha_2 i_{t-2}$

$$-(1-\alpha^f)(\beta_1^f \pi_{t+12}^* + \beta_2^f y_t^*) - \alpha_1^f i_{t-1}^* - \alpha_2^f i_{t-2}^* + \varepsilon_t$$

Note: The table collects the empirical interest rate rule implied exchange rate equations discussed in the text.

Table 2: Exchange Rate Models Based on Optimal Interest Rate Rules

Homogeneous Specifications

T1:Learning – $E_t\Delta s_{t+1} = \beta_0 + \beta_1 \widehat{E}_t(\pi_{t+1} - \pi^*_{t+1}) + \beta_2 \widehat{E}_t(y_{t+1} - y^*_{t+1}) + \beta_3(y_{t-1} - y^*_{t-1}) + \varepsilon_t$

T2: Interest Rate Inertia – $E_t\Delta s_{t+1} = \beta_0 + \alpha_1(i_{t-1} - i^*_{t-1}) + \alpha_2(\Delta i_{t-1} - \Delta i^*_{t-1}) + \beta_1(\pi_t - \pi^*_t) + \beta_2(\Delta y_t - \Delta y^*_t) + \varepsilon_t$

T3: Inflation Inertia – $E_t\Delta s_{t+1} = \beta_0 + \alpha_1(i_{t-1} - i^*_{t-1}) + \alpha_2(\Delta i_{t-1} - \Delta i^*_{t-1}) + \beta_1[F_t(\pi) - F^*_t(\pi)] + \beta_2[F_t(y) - F^*_t(y)]$
$-\beta_3(\pi_{t-1} - \pi^*_{t-1}) - \beta_4(y_{t-1} - y^*_{t-1}) + \epsilon_t$

T4: Inflation Targeting – $E_t\Delta s_{t+1} = \beta_0 + \alpha_1(i_{t-1} - i^*_{t-1}) + \alpha_2(\Delta i_{t-1} - \Delta i^*_{t-1}) + \beta_1(\pi_t - \pi^*_t) + \varepsilon_t$

T5: Money Growth – $E_t\Delta s_{t+1} = \beta_0 + \alpha_1(i_{t-1} - i^*_{t-1}) + \beta_1[(\pi_t - k_t) - (\pi^*_t - k^*_t)] + \beta_2(g_{y,t} - g^*_{y,t}) + \varepsilon_t$

Heterogeneous Specifications

T1: Learning – $E_t\Delta s_{t+1} = \beta_0 + \beta_1 \widehat{E}_t\pi_{t+1} + \beta_2 \widehat{E}_t y_{t+1} + \beta_3 y_{t-1} - (\beta^f_1 \widehat{E}_t\pi^*_{t+1} + \beta^f_2 \widehat{E}_t y^*_{t+1} + \beta^f_3 y^*_{t-1}) + \varepsilon_t$

T2: Interest Rate Inertia – $E_t\Delta s_{t+1} = \beta_0 + \alpha_1 i_{t-1} + \alpha_2\Delta i_{t-1} + \beta_1\pi_t + \beta_2\Delta y_t - (\alpha^f_1 i^*_{t-1} + \alpha^f_2\Delta i^*_{t-1} + \beta^f_1\pi^*_t + \beta^f_2\Delta y^*_t) + \varepsilon_t$

T3: Inflation Inertia – $E_t\Delta s_{t+1} = \beta_0 + \alpha_1 i_{t-1} + \alpha_2\Delta i_{t-1} + \beta_1 F_t(\pi) + \beta_2 F_t(y) - \beta_3\pi_{t-1} - \beta_4 y_{t-1}$
$-[\alpha^f_1 i^*_{t-1} + \alpha^f_2\Delta i^*_{t-1} + \beta^f_1 F^*_t(\pi) + \beta^f_2 F^*_t(y) - \beta^f_3\pi^*_{t-1} - \beta^f_4 y^*_{t-1}] + \epsilon_t$

T4: Inflation Targeting – $E_t\Delta s_{t+1} = \beta_0 + \alpha_1 i_{t-1} + \alpha_2\Delta i_{t-1} + \beta_1\pi_t - (\alpha^f_1 i_{t-1} + \alpha^f_2\Delta i^*_{t-1} + \beta^f_1\pi^*_t) + \varepsilon_t$

T5: Money Growth – $E_t\Delta s_{t+1} = \beta_0 + \alpha_1 i_{t-1} + \beta_1(\pi_t - k_t) + \beta_2 g_{y,t} + [\alpha^f_1 i^*_{t-1} + \beta^f_1(\pi^*_t - k^*_t) + \beta^f_2 g^*_{y,t}] + \varepsilon_t$

Note: The table collects the optimal interest rate rule implied exchange rate equations discussed in the text and appendix.

Table 3: Results of Estimating Exchange Rate Equations Based on Empirical Interest Rate Rules with Homogenous Coefficients

	BP/$			CAN$/$			YEN/$			SF/$			DM/$		
	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3
β_1	0.078	0.062	0.121	-0.004	-0.032	-0.021	-0.106	-0.125	0.171**	0.037	0.037	0.244*	0.007	-0.050	0.139
	(0.065)	(0.067)	(0.104)	(0.055)	(0.033)	(0.039)	(0.145)	(0.134)	(0.079)	(0.095)	(0.077)	(0.129)	(0.115)	(0.106)	(0.097)
β_2	-0.119	-0.087	-0.096	-0.021	-0.013	-0.016	-0.142	-0.148	-0.091	0.054	0.043	-0.163	0.036	0.258***	0.252**
	(0.122)	(0.112)	(0.118)	(0.080)	(0.048)	(0.079)	(0.158)	(0.168)	(0.111)	(0.101)	(0.091)	(0.164)	(0.099)	(0.079)	(0.119)
α_1	0.088	0.091	0.076	-0.060	-0.056	-0.057	0.299	0.295	0.154	-0.243*	-0.241*	-0.175	0.201	0.126	0.061
	(0.164)	(0.187)	(0.181)	(0.068)	(0.066)	(0.067)	(0.267)	(0.261)	(0.298)	(0.136)	(0.128)	(0.122)	(0.195)	(0.199)	(0.176)
α_2	-0.039	-0.040	-0.043	0.127**	0.133***	0.128***	-0.323	-0.301	-0.332	0.125	0.119	0.147	-0.181	-0.175	-0.141
	(0.133)	(0.152)	(0.154)	(0.053)	(0.045)	(0.048)	(0.285)	(0.262)	(0.296)	(0.213)	(0.195)	(0.208)	(0.235)	(0.221)	(0.208)
Adj. R-sq.	-0.012	-0.023	-0.009	-0.015	-0.014	-0.015	0.002	0.003	0.027	-0.026	-0.026	-0.010	-0.030	0.003	-0.042
AIC	2.273	2.284	2.271	0.833	0.831	0.833	2.486	2.485	2.461	2.850	2.850	2.835	2.391	2.358	2.402
SBC	2.398	2.408	2.395	0.966	0.965	0.966	2.610	2.609	2.585	2.991	2.991	2.975	2.516	2.483	2.527
Ranking	2	3	1	2	1	2	3	2	1	2	2	1	2	1	3

Note: The columns labeled E1, E2, and E3 present the results of estimating exchange rate equations (5), (8), and (11), respectively. These equations are based on empirical interest rate rules that have the same domestic and foreign response coefficients. Robust standard errors are reported in parentheses underneath coefficient estimates. "***", "**" and "*" indicate significance at the 1%, 5% and 10% level. Equations are estimated by OLS and GMM. AIC and SBC stand for, respectively, Akaike Information Criterion and Schwartz Bayesian Criterion. The adjusted R-square estimates are given in the row “Adj. R-sq.” Rankings of the models are based on the smallest AIC values. The intercept estimates are not reported for brevity. The sample period is 1974:01-1983:12.

Table 4: Performance of Exchange Rate Equations Based on Empirical Interest Rate Rules with Homogenous Coefficients

	BP/$			CAN$/$			YEN/$			SF/$			DM/$		
	M	R	F	M	R	F	M	R	F	M	R	F	M	R	F
Panel a: E1															
AIC	2.188	1	60%	0.725	2	24%	2.429	2	39%	2.538	1	25%	2.523	3	11%
SBC	2.305	1	60%	0.841	2	24%	2.545	2	39%	2.655	1	25%	2.639	3	11%
R-square	0.022	1	60%	0.015	2	25%	0.029	2	36%	0.004	1	25%	-0.007	3	6%
MSFE	9.127	2	30%	2.763	2	33%	10.423	2	28%	11.666	2	25%	12.629	2	34%
Panel b: E2															
AIC	2.191	2	28%	0.721	1	59%	2.427	1	47%	2.540	2	48%	2.523	2	27%
SBC	2.308	2	28%	0.837	1	59%	2.544	1	47%	2.657	2	48%	2.639	2	27%
R-square	0.019	2	30%	0.019	1	59%	0.030	1	47%	0.002	2	39%	-0.006	2	27%
MSFE	9.096	1	30%	2.724	1	28%	10.292	1	36%	11.683	3	27%	12.852	3	33%
Panel c: E3															
AIC	2.227	3	12%	0.741	3	17%	2.437	3	15%	2.550	3	28%	2.516	1	62%
SBC	2.343	3	12%	0.858	3	17%	2.553	3	15%	2.668	3	28%	2.632	1	62%
R-square	-0.018	3	10%	-0.003	3	16%	0.022	3	18%	-0.003	3	36%	0.004	1	67%
MSFE	9.787	3	40%	2.841	3	38%	10.333	3	36%	11.461	1	48%	12.439	1	33%

Note: Some in-sample and out-of-sample forecast performance measures of the exchange rate equations (5), (8), and (11) are presented in Panels E1, E2, and E3, respectively. Results are based on a 10-years rolling window regression. The initial sample of rolling regression is 1974:01-1983:12 and the final sample is 1999:01-2008:12. The row “AIC” (“SBC”) gives the AIC (SBC) values of individual estimated models, “R-square” gives the adjusted R-square estimates, “MSFE” gives the average of the squared one-step ahead prediction errors. The column labeled “M” gives the means of these measures. The column “R” gives a model’s rankings based on the average values of the measures listed in the first column, and the column “F” gives the frequencies at which a model is selected as the best one.

Table 5: Results of Estimating Exchange Rate Equations Based on Empirical Interest Rate Rules with Heterogeneous Coefficients

	BP/$			CAN$/$			YEN/$			SF/$			DM/$		
	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3
β_1	0.162**	0.139**	0.234***	0.043	-0.051	0.086	-0.069	-0.021	0.354***	-0.368	-0.927	0.698	-0.253	-0.929	0.618
	(0.077)	(0.069)	(0.077)	(0.124)	(0.101)	(0.076)	(0.176)	(0.133)	(0.101)	(0.623)	(1.539)	(0.445)	(0.547)	(0.704)	(0.443)
β_2	-0.295**	-0.259	-0.213**	0.001	0.005	-0.044	-0.078	-0.072	-0.016	-0.235	-1.059	-0.236	-0.196	0.167	-0.086
	(0.124)	(0.162)	(0.105)	(0.084)	(0.060)	(0.081)	(0.103)	(0.101)	(0.083)	(0.599)	(1.835)	(0.398)	(0.256)	(0.170)	(0.194)
α_1	0.136	0.170	-0.111	-0.062	-0.049	-0.015	-1.061	-1.108**	-1.479	-0.102	0.053	-0.641	0.938***	0.975***	0.795
	(0.156)	(0.153)	(0.170)	(0.065)	(0.054)	(0.086)	(0.702)	(0.559)	(1.035)	(0.361)	(0.327)	(0.485)	(0.384)	(0.363)	(0.597)
α_2	-0.040	-0.077	0.056	0.101**	0.129**	0.088	0.912**	0.787**	1.024	0.344	0.497	0.639	-0.542	-0.574	-0.605
	(0.147)	(0.152)	(0.166)	(0.055)	(0.061)	(0.066)	(0.462)	(0.400)	(0.993)	(0.363)	(0.342)	(0.455)	(0.389)	(0.390)	(0.485)
β_1^f	-0.562***	-0.484***	-0.531***	-0.008	0.007	-0.022	0.179	0.254	-0.122	0.046	0.231	-0.182	0.009	0.082	-0.159
	(0.171)	(0.138)	(0.159)	(0.042)	(0.026)	(0.051)	(0.176)	(0.177)	(0.209)	(0.174)	(0.141)	(0.131)	(0.071)	(0.068)	(0.147)
β_2^f	0.029	-0.033	-0.079	0.017	0.053	0.029	-0.012	-0.153	-0.294	-0.282	-0.534	-0.024	-0.123	-0.421	-0.095
	(0.183)	(0.203)	(0.228)	(0.091)	(0.070)	(0.076)	(0.269)	(0.289)	(0.378)	(0.272)	(0.340)	(0.193)	(0.127)	(0.109)	(0.161)
α_1^f	0.146	0.155	0.124	0.034	0.047	0.170	-0.401	-0.381	-0.074	0.305	0.313*	0.105	0.047	0.092	0.073
	(0.264)	(0.251)	(0.275)	(0.127)	(0.137)	(0.133)	(0.334)	(0.306)	(0.354)	(0.269)	(0.169)	(0.291)	(0.148)	(0.164)	(0.237)
α_2^f	0.023	0.006	0.008	-0.116	-0.144	-0.276*	0.499*	0.514*	0.445	-0.055	-0.022	-0.200	-0.146	-0.124	-0.168
	(0.257)	(0.226)	(0.242)	(0.121)	(0.136)	(0.162)	(0.307)	(0.276)	(0.353)	(0.255)	(0.237)	(0.283)	(0.172)	(0.158)	(0.257)
Adj. R-sq.	0.066	0.042	0.046	-0.054	-0.046	-0.064	-0.002	0.006	0.058	-0.051	0.024	-0.045	0.007	0.047	0.006
AIC	2.295	2.320	2.317	0.909	0.901	0.918	2.524	2.517	2.463	2.916	2.842	2.910	2.390	2.348	2.390
SBC	2.535	2.561	2.557	1.149	1.142	1.158	2.748	2.740	2.686	3.169	3.096	3.164	2.613	2.571	2.613
Ranking	1	3	2	2	1	3	3	2	1	3	1	2	2	1	3

Note: The results of estimating exchange rate equations (6), (9), and (12) are presented under the columns labeled E1, E2, and E3, respectively. These equations are based on empirical interest rate rules that have different domestic and foreign response coefficients. See Table 3 for additional notes.

Table 6: Performance of Exchange Rate Equations Based on Empirical Interest Rate Rules with Heterogeneous Coefficients

	BP/$			CAN$/$			YEN/$			SF/$			DM/$		
	M	R	F	M	R	F	M	R	F	M	R	F	M	R	F
Panel a: E1															
AIC	2.191	1	58%	0.759	2	24%	2.455	3	17%	2.554	1	50%	2.529	2	33%
SBC	2.400	1	58%	0.969	2	24%	2.664	3	18%	2.764	1	51%	2.738	2	33%
R-square	0.050	1	57%	0.011	2	26%	0.033	3	17%	0.019	1	53%	0.019	2	33%
MSFE	9.206	1	31%	2.866	3	34%	10.555	2	36%	12.260	1	29%	12.390	2	23%
Panel b: E2															
AIC	2.204	2	24%	0.758	1	67%	2.455	2	37%	2.557	2	26%	2.538	3	8%
SBC	2.413	2	24%	0.967	1	67%	2.664	2	38%	2.768	2	26%	2.747	3	8%
R-square	0.037	2	24%	0.013	1	67%	0.033	2	37%	0.016	2	26%	0.010	3	8%
MSFE	9.219	2	31%	2.836	2	27%	10.481	1	28%	12.484	2	28%	12.896	3	34%
Panel c: E3															
AIC	2.217	3	18%	0.786	3	9%	2.451	1	46%	2.582	3	24%	2.514	1	59%
SBC	2.428	3	18%	0.997	3	9%	2.660	1	45%	2.794	3	23%	2.724	1	59%
R-square	0.026	3	19%	-0.017	3	7%	0.038	1	46%	-0.003	3	21%	0.037	1	60%
MSFE	9.573	3	39%	2.812	1	39%	10.843	3	35%	12.939	3	43%	12.180	1	43%

Note: Some in-sample and forecast performance measures of the exchange rate equations (6), (9), and (12) are presented in Panels E1, E2, and E3, respectively. Results are based on a 10-years rolling window regression. The initial sample of rolling regression is 1974:01-1983:12 and the final sample is 1999:01-2008:12. The row “AIC” (“SBC”) gives the AIC (SBC) values of individual estimated models, “R-square” gives the adjusted R-square estimates, “MSFE” gives the average of the squared one-step ahead prediction errors. The column labeled “M” gives the means of these measures. The column “R” gives a model’s rankings based on the average values of the measures listed in the first column, and the column “F” gives the frequencies at which a model is selected as the best one.

Table 7: Rank Correlation Coefficients of In-Sample and Out-of-Sample Performance Measures:
Exchange Rate Equations Based on Empirical Interest Rate Rules

	Homogenous Models					Heterogeneous Models				
	BP/$	CAN$/$	YEN/$	SF/$	DM/$	BP/$	CAN$/$	YEN/$	SF/$	DM/$
E1	-0.026	-0.086	0.068	0.076	-0.027	-0.021	-0.039	-0.007	0.016	0.045
	(0.653)	(0.139)	(0.244)	(0.193)	(0.718)	(0.719)	(0.504)	(0.903)	(0.783)	(0.550)
E2	0.052	-0.083	-0.009	-0.144	-0.049	0.006	-0.087	-0.055	-0.215	-0.046
	(0.371)	(0.150)	(0.871)	(0.013)	(0.511)	(0.922)	(0.132)	(0.347)	(0.000)	(0.540)
E3	0.022	0.108	-0.015	-0.026	0.045	0.066	0.001	0.006	-0.025	0.002
	(0.714)	(0.068)	(0.796)	(0.659)	(0.559)	(0.262)	(0.985)	(0.918)	(0.678)	(0.977)

Note: Each entry gives the sample correlation between the ranks of the specifications (E1, E2, E3) based on MSFEs and AICs generated from the rolling-regression forecasting exercise. P-values are reported in parentheses. The correlation coefficients of rankings based on MSFEs and SBCs are qualitatively similar to those reported in the Table.

Table 8: Forecasting Evaluation – Exchange Rate Equations Based on Empirical Interest Rate Rules

	BP/$		CAN$/$		YEN/$		SF/$		DM/$	
	MSFE	DOC	MSFE	DOC	MSFE	DOC	MSFE	DOC	MSFE	DOC
Panel a: Homogenous Models										
E-1	0.510	0.924	-0.008	2.078**	0.191	3.002***	0.430	1.386	0.904*	3.130***
E-2	0.376	1.326	-0.025	2.478***	0.116	1.672*	0.589	0.288	1.149*	0.966
E-3	1.074**	0.825	0.103	1.886*	0.150	2.121**	0.231	2.121**	0.764	2.932***
Panel b: Heterogeneous Models										
E-1	0.272	3.233***	-0.009	3.580***	0.272	2.194**	1.227***	1.732*	0.740	4.323***
E-2	0.213	3.170***	0.093	3.516***	0.206	1.787*	1.644***	2.248**	1.242	1.710*
E-3	0.862**	3.064***	0.075	2.239**	0.665	2.593***	1.712***	1.296	0.578	3.086***

Note: The table reports the Diebold-Mariano MSFE and direction of change test statistics. The "MSFE" column gives the MSFE statistics. Significance at the 1%, 5% and 10% levels based on bootstrapped distributions are indicated by "***", "**" and "*". The direction of change statistics are given under the heading "DOC."

Table 9: Results of Estimating Exchange Rate Equations Based on Optimal Interest Rate Rules with Homogenous Coefficients

	BP/$					CAN$/$					YEN/$				
	T1	**T2**	**T3**	**T4**	**T5**	**T1**	**T2**	**T3**	**T4**	**T5**	**T1**	**T2**	**T3**	**T4**	**T5**
β_1	0.062	0.071	0.113	0.073	0.036	0.053	0.002	0.029	0.004	0.011	-0.132**	-0.100	0.353	-0.100	-0.051
	(0.065)	(0.062)	(0.130)	(0.063)	(0.048)	(0.061)	(0.037)	(0.059)	(0.037)	(0.024)	(0.065)	(0.145)	(0.249)	(0.146)	(0.063)
β_2	-0.223	-0.088	-0.040		0.003	0.235	-0.041	-0.231***		0.003	0.471*	-0.026	-0.046		0.016
	(0.224)	(0.172)	(0.185)		(0.131)	(0.166)	(0.115)	(0.078)		(0.030)	(0.271)	(0.206)	(0.177)		(0.065)
β_3	0.095		-0.030			-0.140		-0.133***			-0.416**		-0.404*		
	(0.194)		(0.131)			(0.106)		(0.047)			(0.189)		(0.208)		
β_4			-0.099					0.043					-0.221		
			(0.120)					(0.052)					(0.155)		
α_1		0.005	0.054	0.015	-0.205		0.065	0.077	0.064	0.013		-0.042	-0.013	-0.040	-0.087
		(0.144)	(0.124)	(0.133)	(0.201)		(0.061)	(0.054)	(0.060)	(0.059)		(0.121)	(0.092)	(0.121)	(0.054)
α_2		0.040	0.042	0.040			-0.127**	-0.131***	-0.125***			0.251	0.276	0.249	
		(0.145)	(0.157)	(0.149)			(0.043)	(0.044)	(0.044)			(0.238)	(0.272)	(0.232)	
Adj. R-sq.	0.014	-0.021	-0.036	-0.014	-0.018	-0.05	-0.01	-0.01	0.00	-0.03	-0.07	-0.01	0.00	0.00	0.00
AIC	2.239	2.283	2.315	2.267	2.805	0.854	0.832	0.844	0.812	0.837	2.551	2.494	2.508	2.475	2.483
SBC	2.338	2.407	2.489	2.366	2.905	0.961	0.965	1.031	0.919	0.944	2.650	2.618	2.682	2.575	2.582
Ranking	1	4	5	2	3	5	2	4	1	3	5	3	4	1	2

Note: The columns labeled T1, T2, T3, T4, and T5 present the results of estimating exchange rate equations that are given in Table 2. These equations are based on theoretically optimal interest rate rules that have the same domestic and foreign response coefficients. Robust standard errors are reported in parentheses underneath coefficient estimates. Equations are estimated by OLS and GMM. The intercept estimates are not reported for brevity. The sample period is 1974:01-1983:12, except T5 for UK which is 1984:01-1993:12 due to data availability on the money supply series. See Table 3 for additional notes.

Table 9: Continue

	SF/$					DM/$				
	T1	**T2**	**T3**	**T4**	**T5**	**T1**	**T2**	**T3**	**T4**	**T5**
β_1	0.052	0.050	0.509	0.049	-0.007	-0.050	0.012	0.726***	0.009	0.090
	(0.115)	(0.093)	(0.380)	(0.090)	(0.046)	(0.090)	(0.111)	(0.168)	(0.122)	(0.038)
β_2	-0.744	0.094	0.020		0.072	-0.148	-0.313*	-0.461***		0.085
	(0.510)	(0.732)	(0.188)		(0.079)	(0.422)	(0.187)	(0.171)		(0.066)
β_3	0.623		-0.391			0.339		-0.675***		
	(0.413)		(0.331)			(0.233)		(0.150)		
β_4			-0.060					0.316***		
			(0.172)					(0.109)		
α_1		-0.114	-0.025	-0.118	-0.105		0.001	-0.071	0.030	0.076
		(0.117)	(0.169)	(0.124)	(0.107)		(0.125)	(0.113)	(0.129)	(0.110)
α_2		-0.117	-0.153	-0.112			0.239	0.223	0.187	
		(0.199)	(0.214)	(0.198)			(0.201)	(0.186)	(0.220)	
Adj. R-sq.	-0.12	-0.03	-0.03	-0.01	-0.01	0.04	0.00	0.06	-0.02	0.00
AIC	2.926	2.851	2.874	2.828	2.825	2.315	2.360	2.312	2.373	2.351
SBC	3.038	2.991	3.071	2.941	2.937	2.415	2.484	2.486	2.473	2.451
Ranking	5	3	4	2	1	2	4	1	5	3

Table 10: Results of Estimating Exchange Rate Equations Based on Optimal Interest Rate Rules with Heterogeneous Coefficients

	BP/$					**CAN$/$**					**YEN/$**				
	T1	**T2**	**T3**	**T4**	**T5**	**T1**	**T2**	**T3**	**T4**	**T5**	**T1**	**T2**	**T3**	**T4**	**T5**
β_1	-0.001	0.200***	0.204**	0.202***	0.079	-0.020	-0.001	0.419*	0.001	0.077***	-0.162*	-0.076	0.957	-0.107	-0.058
	(0.054)	(0.042)	(0.084)	(0.044)	(0.094)	(0.080)	(0.084)	(0.240)	(0.083)	(0.025)	(0.095)	(0.184)	(0.636)	(0.184)	(0.097)
β_2	-0.293**	-0.103	-0.148		-0.108	0.127**	-0.071	-0.056		0.043	0.003	0.103	-0.318		-0.003
	(0.142)	(0.151)	(0.141)		(0.126)	(0.054)	(0.122)	(0.108)		(0.029)	(0.205)	(0.232)	(0.564)		(0.047)
β_3	0.005		-0.038			-0.075		-0.271**			-0.128		-0.462		
	(0.135)		(0.081)			(0.081)		(0.138)			(0.219)		(0.399)		
β_4			-0.140					0.013					-0.156		
			(0.138)					(0.055)					(0.153)		
α_1		0.069	0.025	0.082	-0.719***		0.021	0.070	0.034	-0.068		-0.075	-0.559*	-0.059	-0.133
		(0.078)	(0.087)	(0.064)	(0.230)		(0.060)	(0.058)	(0.060)	(0.062)		(0.229)	(0.289)	(0.232)	(0.322)
α_2		0.049	0.107	0.056			-0.115**	-0.118**	-0.102**			-0.822	-0.934*	-1.049**	
		(0.150)	(0.151)	(0.150)			(0.041)	(0.053)	(0.047)			(0.559)	(0.541)	(0.485)	
β_1^f	-0.101	-0.483***	-0.126	-0.482***	0.069	-0.030	-0.006	0.110	0.004	-0.043*	0.182	0.133	0.093	0.137	0.034
	(0.127)	(0.071)	(0.400)	(0.071)	(0.055)	(0.045)	(0.036)	(0.119)	(0.035)	(0.026)	(0.114)	(0.179)	(0.331)	(0.181)	(0.075)
β_2^f	0.157	0.079	0.104		-0.277*	-0.064	-0.315	0.001		-0.033	0.233	0.350	0.284		-0.066
	(0.151)	(0.296)	(0.204)		(0.144)	(0.109)	(0.250)	(0.210)		(0.026)	(0.203)	(0.402)	(0.434)		(0.085)
β_3^f	-0.126		-0.325			0.063		-0.204			-0.212		-0.040		
	(0.203)		(0.392)			(0.098)		(0.226)			(0.193)		(0.320)		
β_4^f			-0.098					-0.034					-0.259		
			(0.163)					(0.047)					(0.171)		
α_1^f		0.215**	0.233*	0.200**	0.514**		-0.063	-0.075	-0.059	-0.030		0.104	0.408***	0.078	0.100
		(0.102)	(0.123)	(0.093)	(0.216)		(0.068)	(0.050)	(0.069)	(0.052)		(0.147)	(0.112)	(0.142)	(0.069)
α_2^f		0.011	0.006	0.038			0.150	0.098	0.101			-0.587*	-0.709**	-0.491*	
		(0.258)	(0.219)	(0.232)			(0.144)	(0.119)	(0.117)			(0.342)	(0.313)	(0.281)	
Adj. R-sq.	0.052	0.028	0.017	0.042	0.038	-0.034	-0.010	-0.038	-0.033	-0.017	-0.019	0.002	0.009	0.014	-0.023
AIC	2.149	2.188	2.230	2.159	2.732	0.802	0.796	0.857	0.801	0.785	2.524	2.520	2.546	2.491	2.528
SBC	2.313	2.400	2.536	2.323	2.897	0.978	1.022	1.184	0.977	0.961	2.698	2.744	2.869	2.665	2.702
Ranking	1	3	4	2	5	4	2	5	3	1	3	2	4	1	5

Note: The columns labeled T1, T2, T3, T4, and T5 present the results of estimating exchange rate equations that are given in Table 2. These equations are based on theoretically optimal interest rate rules that have heterogeneous domestic and foreign response coefficients. See Table 9 for additional notes.

Table 10: Continue

	SF/$					DM/$				
	T1	**T2**	**T3**	**T4**	**T5**	**T1**	**T2**	**T3**	**T4**	**T5**
β_1	0.207	-0.169	0.981**	-0.114	-0.023	0.431*	0.165	1.023*	0.102	-0.126
	(0.184)	(0.187)	(0.468)	(0.237)	(0.064)	(0.221)	(0.264)	(0.562)	(0.331)	(0.114)
β_2	0.293	0.606	0.200		0.060	-0.305*	-0.175	-0.376		0.022
	(0.203)	(0.411)	(0.227)		(0.130)	(0.158)	(0.171)	(0.238)		(0.091)
β_3	-0.439**		-0.747*			0.260**		-0.662		
	(0.218)		(0.449)			(0.122)		(0.678)		
β_4			-0.239					0.198		
			(0.185)					(0.138)		
α_1		0.212	0.381	0.074	-0.099		0.335**	0.127	0.396*	0.562**
		(0.343)	(0.698)	(0.396)	(0.310)		(0.155)	(0.216)	(0.205)	(0.271)
α_2		-0.402	-0.379	-0.289			0.472	0.648*	0.439	
		(0.288)	(0.403)	(0.282)			(0.368)	(0.370)	(0.369)	
β_1^f	0.162	-0.050	0.177	-0.071	-0.063	0.045	-0.029	-0.319	-0.047	-0.073
	(0.112)	(0.096)	(0.389)	(0.109)	(0.082)	(0.072)	(0.072)	(0.323)	(0.093)	(0.079)
β_2^f	0.528***	1.076**	-0.066		-0.133	0.639***	0.837***	0.510***		-0.082
	(0.167)	(0.379)	(0.279)		(0.109)	(0.132)	(0.313)	(0.170)		(0.077)
β_3^f	-0.725***		-0.209			-0.717***		0.208		
	(0.163)		(0.344)			(0.157)		(0.300)		
β_4^f			-0.459***					-0.494***		
			(0.153)					(0.101)		
α_1^f		0.261**	0.110	0.202*	0.116		-0.098	0.026	-0.155	-0.114
		(0.122)	(0.137)	(0.117)	(0.116)		(0.139)	(0.118)	(0.139)	(0.074)
α_2^f		-0.220	0.010	-0.013			-0.074	-0.009	0.114	
		(0.257)	(0.177)	(0.255)			(0.189)	(0.139)	(0.202)	
Adj. R-sq.	0.058	0.040	0.017	-0.034	-0.025	0.083	0.037	0.059	0.004	0.027
AIC	2.683	2.720	2.780	2.776	2.767	2.293	2.358	2.368	2.375	2.352
SBC	2.867	2.957	3.123	2.960	2.952	2.466	2.582	2.691	2.549	2.526
Ranking	1	2	3	4	5	1	3	4	5	2

Table 11: Performance of Exchange Rate Equations Based on Optimal Interest Rate Rules with Homogenous Coefficients

	BP/$			CAN$/$			YEN/$			SF/$			DM/$		
	M	R	F	M	R	F	M	R	F	M	R	F	M	R	F
Panel a: T1															
AIC	2.242	5	14%	0.720	3	29%	2.471	5	20%	2.566	5	10%	2.502	3	14%
SBC	2.335	4	20%	0.813	2	37%	2.564	4	21%	2.660	4	10%	2.595	2	41%
R-square	-0.040	5	16%	0.015	4	21%	-0.021	5	11%	-0.024	5	1%	0.007	3	4%
MSFE	9.459	5	29%	2.713	1	25%	10.258	2	28%	12.032	5	26%	12.751	5	14%
Panel b: T2															
AIC	2.187	3	19%	0.715	2	28%	2.444	3	0%	2.538	3	0%	2.522	5	0%
SBC	2.303	3	3%	0.831	4	0%	2.560	3	0%	2.655	3	0%	2.638	5	0%
R-square	0.024	1	34%	0.024	1	50%	0.013	4	0%	0.004	3	5%	-0.005	4	0%
MSFE	9.255	3	15%	2.718	2	14%	10.432	4	15%	11.607	4	13%	12.649	4	10%
Panel c: T3															
AIC	2.209	4	3%	0.732	5	5%	2.446	4	8%	2.552	4	18%	2.474	1	64%
SBC	2.372	5	1%	0.896	5	1%	2.609	5	0%	2.717	5	1%	2.638	4	1%
R-square	0.016	3	19%	0.022	2	14%	0.028	1	42%	0.011	1	43%	0.059	1	96%
MSFE	9.342	4	25%	2.762	4	21%	10.756	5	21%	11.579	3	19%	12.119	1	37%
Panel d: T4															
AIC	2.181	2	58%	0.715	1	31%	2.430	1	47%	2.524	1	35%	2.514	4	0%
SBC	2.274	2	68%	0.808	1	49%	2.522	1	50%	2.618	1	42%	2.607	3	2%
R-square	0.021	2	29%	0.016	3	10%	0.020	2	26%	0.009	2	30%	-0.006	5	0%
MSFE	9.143	2	18%	2.738	3	11%	10.337	3	12%	11.500	2	14%	12.482	2	14%
*Panel e: T5**															
AIC	2.041	1	5%	0.727	4	8%	2.435	2	26%	2.531	2	38%	2.497	2	21%
SBC	2.134	1	8%	0.820	3	13%	2.528	2	30%	2.624	2	47%	2.590	1	55%
R-square	-0.002	4	3%	0.004	5	5%	0.016	3	21%	0.003	4	21%	0.012	2	0%
MSFE	5.837	1	13%	2.823	5	30%	10.171	1	23%	11.429	1	28%	12.602	3	25%

Note: Some in-sample and out-of-sample performance measures of the exchange rate equations under theoretically optimal interest rate rules with homogenous response coefficients are presented in Panels T1 to T5. See Table 4 for additional notes.
*Due to data limitation on money supply for the UK, the out-of-sample forecast starts after 1994:01. Thus, Model 5 for UK is only compared with other equations for a limited sample.

Table 12: Performance of Exchange Rate Equations Based on Optimal Interest Rate Rules with Heterogeneous Coefficients

	BP/$			CAN$/$			YEN/$			SF/$			DM/$		
	M	R	F	M	R	F	M	R	F	M	R	F	M	R	F
Panel a: T1															
AIC	2.216	4	18%	0.726	1	40%	2.466	3	15%	2.549	4	31%	2.494	1	58%
SBC	2.379	3	24%	0.888	1	41%	2.628	3	19%	2.712	2	33%	2.657	1	60%
R-square	0.011	4	18%	0.026	2	32%	0.008	5	4%	0.008	5	25%	0.037	2	36%
MSFE	9.197	2	27%	2.722	1	22%	10.850	3	23%	12.142	2	26%	12.451	2	21%
Panel b: T2															
AIC	2.192	3	36%	0.743	4	6%	2.466	4	0%	2.545	2	11%	2.518	4	17%
SBC	2.401	4	3%	0.952	4	0%	2.675	4	0%	2.755	4	0%	2.727	4	0%
R-square	0.049	1	45%	0.027	1	21%	0.023	3	2%	0.028	1	26%	0.029	3	8%
MSFE	9.386	4	22%	2.826	4	20%	10.637	2	12%	12.225	3	16%	12.757	4	15%
Panel c: T3															
AIC	2.247	5	1%	0.795	5	1%	2.470	5	7%	2.595	5	2%	2.526	5	3%
SBC	2.550	5	0%	1.099	5	1%	2.773	5	0%	2.901	5	0%	2.830	5	0%
R-square	0.023	3	9%	0.005	5	1%	0.048	1	56%	0.014	3	18%	0.054	1	56%
MSFE	9.917	5	23%	2.991	5	19%	11.296	5	27%	12.630	5	15%	13.216	5	27%
Panel d: T4															
AIC	2.188	2	42%	0.736	3	15%	2.441	1	51%	2.541	1	40%	2.517	3	6%
SBC	2.350	2	69%	0.899	3	19%	2.604	1	53%	2.705	1	49%	2.680	3	19%
R-square	0.038	2	28%	0.019	4	10%	0.032	2	18%	0.016	2	24%	0.015	5	0%
MSFE	9.230	3	15%	2.818	3	11%	10.335	1	16%	11.807	1	16%	12.432	1	16%
*Panel e: T5**															
AIC	2.058	1	3%	0.733	2	38%	2.455	2	27%	2.548	3	16%	2.505	2	16%
SBC	2.221	1	4%	0.896	2	39%	2.618	2	28%	2.712	3	18%	2.668	2	20%
R-square	0.005	5	1%	0.022	3	36%	0.020	4	20%	0.009	4	7%	0.028	4	1%
MSFE	6.373	1	14%	2.813	2	28%	10.892	4	23%	12.518	4	28%	12.492	3	20%

Note: Some in-sample and out-of-sample performance measures of the exchange rate equations under theoretically optimal interest rate rules with heterogeneous response coefficients are presented in Panels T1 to T5. See Table 4 for additional notes.

*Due to data limitation on money supply for the UK, the out-of-sample forecast starts after 1994:01. Thus, Model 5 for UK is only compared with other equations for a limited sample.

Table 13: Rank Correlation Coefficients of In-Sample and Out-of-Sample Performance Measures: Exchange Rate Equations Based on Theoretically Optimal Interest Rate Rules

	Homogenous Models					Heterogeneous Models				
	BP/$	CAN$/$	YEN/$	SF/$	DM/$	BP/$	CAN$/$	YEN/$	SF/$	DM/$
T1	0.113	0.069	-0.006	-0.017	0.000	0.053	-0.021	-0.033	-0.088	-0.005
	(0.051)	(0.236)	(0.916)	(0.765)	(0.998)	(0.360)	(0.724)	(0.576)	(0.129)	(0.951)
T2	0.026	-0.052	0.014	0.046	0.112	0.021	-0.081	-0.141	0.001	0.047
	(0.659)	(0.372)	(0.810)	(0.429)	(0.134)	(0.722)	(0.163)	(0.015)	(0.994)	(0.529)
T3	-0.012	-0.075	-0.167	-0.004	0.027	0.107	-0.008	-0.158	0.018	-0.234
	(0.843)	(0.205)	(0.005)	(0.941)	(0.732)	(0.071)	(0.891)	(0.007)	(0.761)	(0.002)
T4	-0.032	0.042	-0.096	0.016	-0.027	-0.060	-0.022	-0.093	0.021	-0.050
	(0.583)	(0.466)	(0.096)	(0.784)	(0.718)	(0.300)	(0.706)	(0.108)	(0.713)	(0.506)
T5	-0.169	-0.047	-0.131	-0.092	0.243	-0.015	-0.037	-0.041	-0.022	0.008
	(0.020)	(0.417)	(0.023)	(0.112)	(0.001)	(0.835)	(0.523)	(0.481)	(0.705)	(0.919)

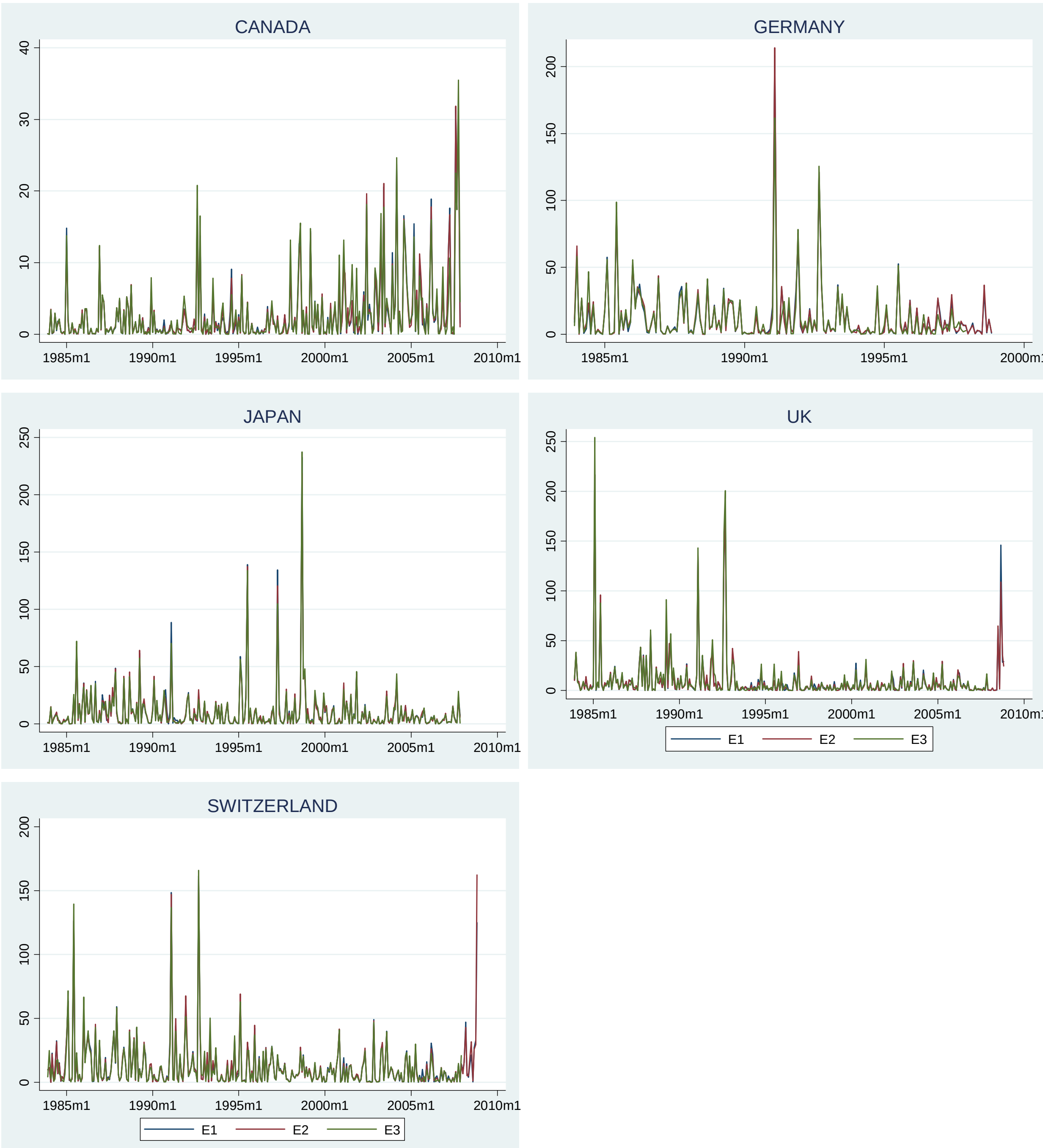
Note: Each entry gives the sample correlation between the ranks of the specifications (T1, T2, T3, T4, T5) based on MSFEs and AICs generated from the rolling-regression forecasting exercise. P-values are reported in parentheses. The correlation coefficients of rankings based on MSFEs and SBCs are qualitatively similar to those reported in the Table.

Table 14: Forecasting Evaluation – Exchange Rate Equations Based on Theoretically Optimal Interest Rate Rules

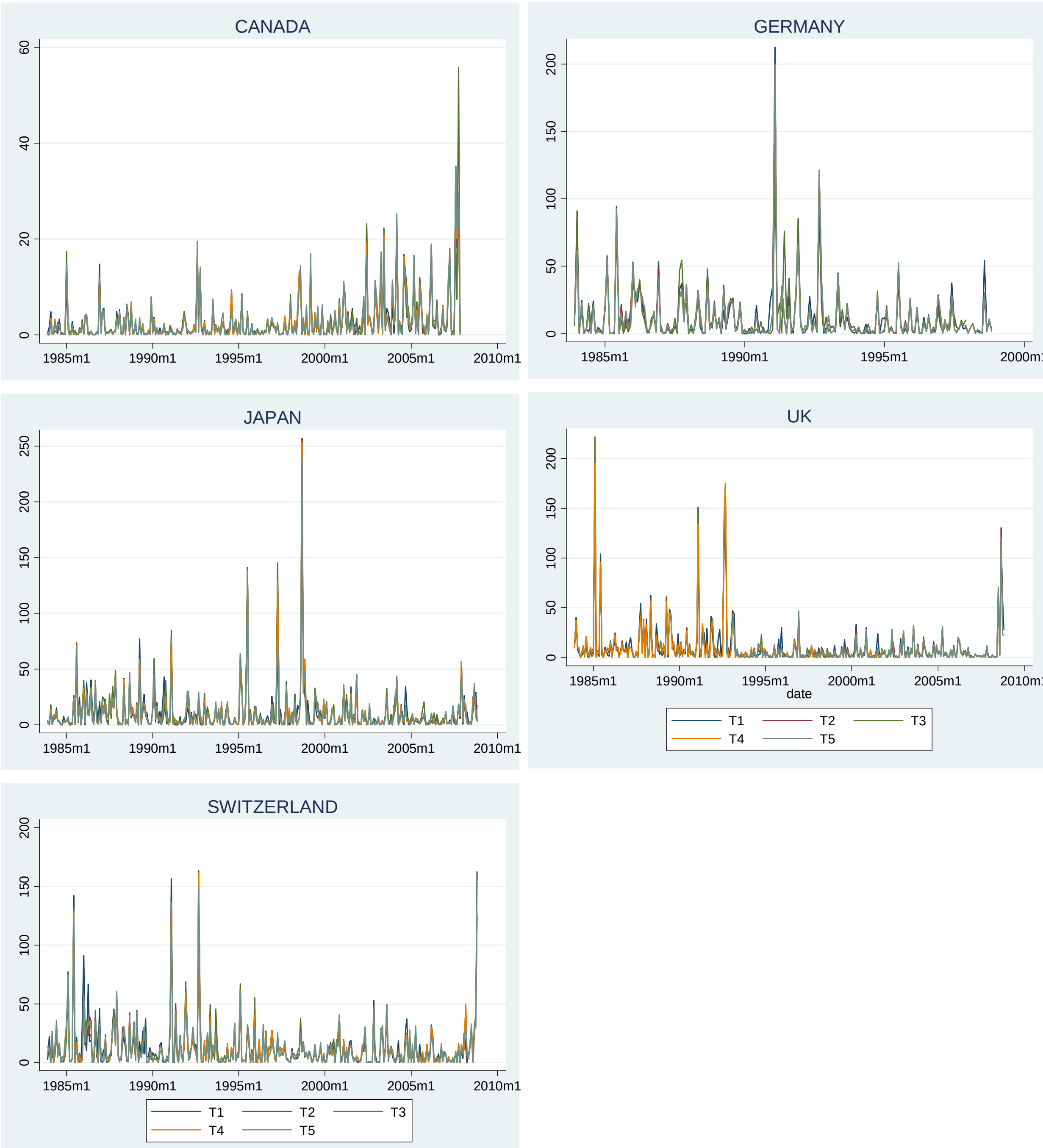
	BP/$		CAN$/$		YEN/$		SF/$		DM/$	
	MSFE	DOC	MSFE	DOC	MSFE	DOC	MSFE	DOC	MSFE	DOC
Panel a: Homogenous Models										
T-1	0.827***	0.405	0.009	1.561	0.038	0.520	0.820**	0.867	1.144**	1.570
T-2	0.613**	0.693	-0.137	1.617	0.170	2.656	0.384	2.078**	0.919*	3.130***
T-3	0.627*	2.239**	0.024	3.300***	0.575	2.711	0.363	2.121**	0.443	3.549***
T-4	0.437*	0.577	-0.023	2.194**	0.087	2.887	0.268	1.270	0.760	2.236**
T-5	0.425**	0.433	0.068	3.233***	-0.037	1.848	0.334	1.848*	0.865	2.832***
Panel b: Heterogeneous Models										
T-1	0.421	1.561	0.052	3.412***	0.695*	1.561	1.169**	2.255***	0.927	1.570
T-2	0.571	2.771***	-0.053	2.887***	0.359	1.617	1.208**	3.926***	1.056*	3.280***
T-3	1.181***	5.118***	0.246	4.765***	1.113*	4.412	1.389***	3.353***	1.540*	3.462***
T-4	0.324	1.386	0.055	3.580***	0.060	2.078	0.735*	3.580***	0.755	3.429***
T-5	0.961**	3.175***	0.128	3.118***	0.658	2.771	1.462***	1.962**	0.872	2.534***

Note: The table reports the Diebold-Mariano MSFE and direction of change test statistics. The “MSFE” column gives the MSFE statistics. Significance at the 1%, 5% and 10% levels based on bootstrapped distributions are indicated by "***", "**" and "*". The direction of change statistics are given under the heading “DOC.”

Graph 1: Forecast Error of Exchange Rate Models Based on Empirical Interest Rate Rules with Homogenous Coefficients



Graph 2: Forecast Error of Exchange Rate Models Based on Optimal Interest Rate Rules with Homogenous Coefficients



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