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Joseph D. ALBA
Nanyang Technological University

Donghyun PARK
Asian Development Bank

Taojun XIE
Singapore Management University, tjxie@smu.edu.sg

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Predictability of Exchange Rates With Taylor Rule Fundamentals: Evidence from Inflation-Targeting Emerging Countries

Joseph D. Alba[1], Donghyun Park[2], and Taojun Xie[3]

[1]Division of Economics, School of Humanities and Social Sciences, Nanyang Technological University, Singapore; [2]Economics and Research Department, Asian Development Bank, Mandaluyong City, Metro Manila, Philippines; [3]Sim Kee Boon Institute for Financial Economics, Singapore Management University, Singapore

ABSTRACT: We investigate the out-of-sample predictability of U.S. dollar exchange rates with Taylor rule fundamentals in thirteen emerging countries with inflation-targeting monetary policy regimes. We find some evidence of out-of-sample exchange rate predictability for Brazil, Czech Republic, Hungary, Philippines, Thailand, and South Africa. Plots of the coefficients of U.S. inflation and Philippine inflation predict the direction of the U.S. dollar–Philippine peso exchange rates to be opposite to that predicted by the Taylor principle.

KEY WORDS: emerging countries, exchange rate, inflation targeting, out-of-sample predictability, Taylor rule

A large literature has emerged in the post-Bretton Woods period to explain exchange rate movements. However, the seminal work of Meese and Rogoff (1983) casts serious doubts on the ability of open-economy macroeconomic theory to predict exchange rate movements. Cheung et al. (2005) confirm that none of the widely used conventional models for predicting exchange rates consistently outperform the simple random walk model at any time horizon. A number of recent studies use the Taylor (1993) rule to model exchange rates. An example of this literature is Mark (2009), who uses the Taylor rule interest rate reaction functions for the United States and Germany to estimate the dollar–mark real exchange rate. Molodtsova and Papell (2009) examine out-of-sample exchange rate predictability with Taylor rule fundamentals. They experiment with a number of different specifications and use a recently developed inference procedure to assess the out-of-sample predictability of exchange rate models with Taylor rule fundamentals for twelve Organisation for Economic Development (OECD) countries vis-à-vis the U.S. dollar in the post-Bretton Woods period. Molodtsova and Papell's (2009) results provide strong evidence of short-run exchange rate predictability for models based on Taylor rule fundamentals. Exchange rate predictability is significant at the 5 percent level for eleven of the twelve currencies at the one-month horizon. Furthermore, the evidence of out-of-sample predictability is much stronger for Taylor rule models than for conventional models.[1]

For emerging countries, empirical studies that seek to predict exchange rate movements are rare even though many emerging countries have recently adopted inflation-targeting monetary policy regimes and moved toward more flexible exchange rate systems. In this context, several authors examine the out-of-sample predictability of exchange rates in emerging economies using panel error correction (EC) models. For example, Galimberti and Moura (2013) use an endogenous monetary policy through the Taylor rule function in fifteen emerging countries that adopted inflation targeting and flexible exchange rate regime.[2] They find strong evidence of exchange rate predictability, but tests of homogeneity of restrictions in the coefficients reject the null of homogeneity, which indicates the

Address correspondence to Joseph D. Alba, Division of Economics, School of Humanities and Social Sciences, Nanyang Technological University, 14 Nanyang Drive, Singapore 637332. E-mail: ajoalba@ntu.edu.sg

nonpoolability of their sample.[3] The nonpoolability of emerging countries is not surprising since these countries vary a great deal in terms of income and development level, economic structures, and monetary policy.

Moura (2010) and Moura and Carvalho (2010) are among the few country-by-country studies that investigate the out-of-sample predictability of exchange rates in emerging countries. Moura (2010) investigates the predictability of exchange rates of five Latin American countries using error correction models (ECM) that incorporate endogenous monetary policy through a Taylor rule reaction function. He finds strong evidence of exchange rate predictability for the Taylor rule model using the Clark and West (2006, 2007) tests. Moura and Carvalho (2010) add two more Latin American countries to Moura's (2010) sample and examine predictability of exchange rates using sixteen alternative specifications of the Taylor rule. They find evidence of exchange rate predictability for different Taylor rule specifications using the Clark and West (2006, 2007) tests. They also find a wide variety of responses among the seven countries.[4] Kim and Ryu (2014) examine the predictability of the U.S. dollar–Korean won exchange rate using the Taylor rule specification while accounting for uncertainty in the structural breaks using the combination window method. They show out-of-sample predictability of the U.S. dollar–Korean won exchange rate using Clark and West (2006, 2007) tests.

The central objective of our article is to examine country-by-country out-of-sample exchange rate predictability with Taylor rule fundamentals for thirteen inflation-targeting emerging countries in Africa, Asia, and Latin America.[5] Using monthly data, we apply the rigorous empirical framework developed by Molodtsova and Papell (2009) to test for short-run exchange rate predictability of exchange rate models with the Taylor rule, monetary fundamentals, purchasing power parity (PPP), and uncovered interest parity (UIRP). We evaluate the out-of-sample performance of fifty-eight models for each country according to the mean squared prediction error (MPSE) comparison proposed by Clark and West (2006, 2007) (the CW test). Beyond Galimberti and Moura (2013), Moura (2010), and Moura and Carvalho (2010), we test for the out-of-sample performance of a benchmark model compared with a set of alternative models using the test of superior predictive ability (SPA) proposed by Hansen (2005).[6] We look at both the precrisis subsample period (until 2008) and the full sample period (until June 2013) to gauge the effect of the global financial crisis on exchange rate predictability. In addition, we examine whether the models showing evidence of exchange rate predictability produce exchange rate forecasts consistent with the Taylor principles.

Molodtsova-Papell Exchange Rate Models

We examine the out-of-sample predictability of exchange rates of thirteen emerging countries that implemented inflation targeting policies using models of exchange rate determination specified in Molodtsova and Papell (2009). The Molodtsova-Papell (MP) models specify the Taylor's monetary policy rules incorporating bilateral U.S. real exchange rate, q, as

$$\bar{i}_t = \pi_t + \phi(\pi_t - \bar{\pi}) + \gamma \hat{y}_t + \bar{r} + \delta q, \quad (1)$$

where $\bar{i}_t$ is the short-term nominal interest rate target; π_t is the inflation rate; $\bar{\pi}$ is the target level of inflation; $\hat{y}_t$ is the output gap or the percent deviation of actual from potential output; and $\bar{r}$ is the equilibrium real interest rate.[7]

Molodtsova and Papell (2009) allow partial adjustment in the interest rate ($i_t = (1-\rho)\bar{i}_t + \rho i_{t-1} + v_t$) and then derive the forecasting equation between the United States and the foreign country as follows:

$$i_t - i_t^* = \alpha + \alpha_{u\pi}\pi_t - \alpha_{f\pi}\pi_t^* + \alpha_{uy}\hat{y}_t - \alpha_{fy}\hat{y}_t^* - \alpha_q q_t^* + \rho_u i_{t-1} - \rho_f i_{t-1}^* + \eta_t, \quad (2)$$

where * represents the foreign country variable; the subscripts u and f denote the United States and the foreign country, respectively; $\alpha = (\bar{r} - \phi_u\bar{\pi})(1-\rho_u) - (\bar{r}^* - \phi_f\bar{\pi}^*)(1-\rho_f)$; $\delta = 0$ for the United

States; $\alpha_\pi = \lambda(1-\rho)$ and $\alpha_y = \gamma(1-\rho)$ for the United States and the foreign country; and $\alpha_q = \delta(1-\rho)$ for the foreign country.[8]

Molodtsova and Papell (2009) equate the interest differential $(i_t - i_t^*)$ to expected change in nominal exchange rate (Δs_{t+1} where s is the log of U.S. dollars per unit of foreign currency) in Equation (2) but reverse the signs for consistency with the findings of empirical literature, which contradict the uncovered interest rate parity (UIRP) prediction, that a rise in the interest rate differential causes forecast (and actual) appreciation of the s.[9] Hence,

$$\Delta s_{t+1} = \omega - \omega_{u\pi}\pi_t + \omega_{f\pi}\pi_t^* - \omega_{uy}y_t + \omega_{fy}y_t^* + \omega_q q_t^* - \omega_{ui}i_{t-1} + \omega_{fi}i_{t-1}^* + \eta_t. \tag{3}$$

The coefficients in Equation (2) are written as ω's instead of α's because of uncertainty about the magnitude of the adjustment in the exchange rate due to the change in interest rate differential.

Molodtsova and Papell (2009) consider several nested models from Equation (3) as follows: (1) symmetric when the foreign central bank does not target the exchange rate ($\delta = \alpha_q = 0$); otherwise, it is asymmetric; (2) "no smoothing" when interest rate adjustment occurs instantaneously ($\rho_u = \rho_f = 0$); otherwise, there is smoothing;[10] (3) homogenous when the coefficients of inflation, the output gap, and the interest rate smoothing are the same in the United States and the foreign country ($\alpha_{u\pi} = \alpha_{f\pi}$, $\alpha_{uy} = \alpha_{fy}$ and $\rho_u = \rho_f$); otherwise, it is heterogeneous; and (4) no constant when the coefficients on inflation and interest rate smoothing, the inflation targets, and equilibrium real interest rates are equal in the United States and the foreign country ($\alpha = 0$); otherwise, there is a constant. The combinations of these specifications account for sixteen Taylor rule models.

Molodtsova and Papell (2009) also consider the link between exchange rates and fundamentals according to the UIRP, monetary, and PPP models. However, in light of the empirical literature finding that UIRP does not hold in the short run, they modify the model to allow for a rise in the interest rate differential between the United States and the foreign country to cause an appreciation of the U.S. dollar. Hence, the specification of interest rate fundamentals is

$$\Delta s_{t+1} = \alpha + \omega(i_t - i_t^*), \tag{4}$$

where no restriction is placed on the coefficient ω.

The monetary fundamentals model follows Mark (1995), in which the change in the log of the exchange rate over an h-period is given as

$$s_{t+h} - s_t = \alpha_h + \beta_h z_t + v_{t+h,t}, \tag{5}$$

where $z_t = f_t - s_t$; f_t is the long-run equilibrium level of exchange rate determined using flexible price monetary specifications for the domestic country and for the foreign country given by $m_t = p_t + k_u y_t - h_u i_t$ and $m_t^* = p_t^* + k_f y_t^* - h_f i_t^*$, respectively, where m_t is the log of money supply, p_t is the log of price level, and y_t is the log of income. Assuming PPP, UIRP, and no rational speculative bubbles, f_t is derived as

$$f_t = (m_t - m_t^*) - k(y_t - y_t^*), \tag{6}$$

where the income elasticity, k, could take values of zero, one, or three. The exchange rate forecasting equation is derived from the monetary model by substituting Equation (6) into Equation (5).

The PPP fundamentals are derived as

$$f_t = (p_t - p_t^*). \tag{7}$$

Equation (7) is substituted into Equation (5) to derive the exchange rate forecasting equation from PPP fundamentals.

Data and Methodology

We estimate the linear fundamental–based (MP) models and then evaluate their out-of-sample performance using monthly data of thirteen emerging countries that implemented inflation-targeting monetary policies in the late 1990s and early first decade of the 2000s.[11] Since the monetary policies of those countries are geared toward containing inflation, their exchange rates tend to be flexible. The monthly data of the thirteen emerging countries are primarily from the CEIC Macroeconomic Databases for Emerging and Developing Countries. The exchange rate is in terms of U.S. dollar per national currency. The price level is the consumer price index (CPI), and the inflation is the year-on-year change in the CPI. The short-term interest rate is the money market rate for Brazil, Czech Republic, Philippines, Poland, South Africa, and Thailand, the deposit rate for Chile and Hungary, the discount rate for Colombia, Israel, and Peru, and the time deposit rate for Korea and Mexico. Since real gross domestic product (GDP) is not available monthly, seasonally adjusted industrial or manufacturing production index is used as a proxy for output. The industrial production index (IPI) is used for most countries except Peru, Philippines, South Africa, and Thailand, where the manufacturing production index is used.[12] The data for each country span the beginning of inflation targeting until June 2013.

The MP models include the output gap that is calculated using three measures of the potential output: the linear time trend, the quadratic time trend, and the Hodrick-Prescott (HP) trend (Hodrick and Prescott 1997). Quasi-real data of potential output are constructed by running rolling regressions to estimate the linear, quadratic, and HP trends with a rolling window of twenty-four months. The first rolling regression uses data for periods from twenty-four months (t-24) to one month (t-1) before the start date of inflation targeting ($t = 0$). For the linear and quadratic trends, the one-period-ahead projection of the trend is used as the first observation of potential output at $t = 0$. The subsequent observations of potential output are calculated by running rolling regressions to estimate the trends using data of the previous twenty-four periods and then taking one-period-ahead projections of the trends as the values of potential outputs. For the HP trend, the six-months-ahead projection (t to t+5) of the growth rate of output is estimated from the growth rate of output over the past twenty-four months (t-24 to t-1) assuming an AR(6) model. From the six-months-ahead projection of the growth rate of output, the six-months-ahead projection of the level of output is calculated. The actual output data over the past twenty-four months (t-24 to t-1) are combined with the six-months-ahead projected output data (t to t+5), and the series is fitted in an HP filter. The one-period-ahead forecast of potential output is the HP trend at time $t = 0$, which is used as the first observation. The subsequent observations of potential output are similarly calculated.[13]

In evaluating the out-of-sample performance of the above models, we follow Molodtsova and Papell (2009) in using the Clark and West (2006, 2007) (CW) procedure. The CW procedure uses the out-of-sample mean squared prediction errors (MSPEs) to evaluate the null hypothesis of a series following a random walk or a zero mean martingale difference against the alternative hypothesis that it is linearly predictable. The CW test statistic is adjusted to account for the expected greater sample MSPE of the alternative model relative to the random walk model under the null of random walk. Without the adjustment, Clark and West's (2006) simulations show that the hypothesis tests will be poorly sized. Their simulation results also imply that with the MSPE-adjusted CW test statistic, asymptotic normal critical values could be used to make inferences from well-sized hypothesis tests for rolling regressions.[14]

The MP models are estimated using OLS rolling regressions with a window size of sixty periods, and for each regression, a one-period-ahead forecast is constructed.[15] Hence, the first regression uses the first sixty observations to estimate the model, and then a one-period-ahead forecast of the exchange rate is calculated. The second regression drops the first observation and adds the sixty-first observation to estimate the model, and then the one-period-ahead forecast is calculated. The one-period-ahead forecast is calculated for each round until the last observation is used in the OLS regression. The CW statistic is constructed from the adjusted MSPE of the linear model and the MSPE of the random walk model.[16]

Empirical Results

We estimate sixteen Taylor rule models, which are combinations of symmetric and asymmetric, homogeneous and heterogeneous, with and without smoothing, and with and without a constant, together with three measures of the output gap, totaling forty-eight models for each country. We consider the subsample period until June 2008 and the full sample period until June 2013 since the federal funds rate was close to zero after 2008, which may imply that the U.S. Federal Reserve Bank did not follow the Taylor rule.[17]

Tables 1 and 2 show the significance of the CW tests—where *, **, and *** indicate 10 percent, 5 percent, and 1 percent levels of significance, respectively, and blank spaces indicate insignificance at the 10 percent level of significance—of the forty-eight models for each of the thirteen countries. The tables only show the significance of CW test results of countries that are significant at the 10 percent and higher levels of significance for at least one of the models.

The upper (lower) halves of Tables 1 and 2 report the significance of the CW test results for the precrisis subsample (full sample). For the precrisis subsample, there is stronger evidence of exchange rate predictability for symmetric models with heterogeneous coefficients, without smoothing, and with no constant compared to the other models. This is shown in the shaded upper middle columns of Table 1, in which the CW tests are significant in sixteen cases compared with the other models, where significant results vary between five and twelve. The shaded upper columns of Table 1 show some evidence that the Taylor rule outperforms the random walk for six of thirteen countries: Czech Republic, Hungary, Philippines, Poland, South Africa, and Thailand.

The shaded lower middle columns of Table 1 report the significance of the CW tests for symmetric Taylor rule models with heterogeneous coefficients, without smoothing, and with no constant using three measures of the output gaps. They show significant CW tests in thirteen cases for nine countries: Brazil, Colombia, Czech Republic, Hungary, Mexico, Philippines, Poland, South Africa, and Thailand.[18]

For comparative purposes, Table 3 shows the results of the one-month-ahead forecast of exchange rates of models based on UIRP, PPP, and monetary fundamentals. For the precrisis subsample, the random walk model is outperformed by the UIRP model without a constant for Hungary, Poland, and Thailand, and by the UIRP model with a constant for Czech Republic and Poland. The random walk model is also outperformed by the monetary fundamental models without a constant for Czech Republic, Hungary, Peru, Poland, and Thailand and by the monetary models with a constant for Czech Republic, Korea, Poland, and Thailand. In addition, the random walk model is outperformed by the PPP models with a constant for Brazil, Czech Republic, Hungary, Korea, and Poland. By contrast, for the full sample, the UIRP model with a constant for Philippines and the monetary fundamentals models with and without a constant for Thailand outperform the random walk model.

Following Molodtsova and Papell (2009), we conduct the Hansen (2005) test of superior predictive ability (SPA) to ensure that the evidence of predictive ability is genuine rather than arising from extensive data snooping. After all, we test forty-eight models of thirteen bilateral exchange rates, resulting in 1,248 CW test statistics. Molodtsova and Papell (2009) implement the SPA test by comparing the MSPE of the random walk with the adjusted MSPE of the linear model. The null hypothesis is that the MSPE of the random walk is smaller than the adjusted MSPE of the linear model. The null hypothesis indicates that the benchmark model—the random walk—is not inferior to any of the linear models, and the alternative hypothesis indicates that at least one of the linear models has superior predictive ability.

Table 4 shows the indicators of the significance of SPA tests of sixteen Taylor rule models with the random walk as the benchmark model and the three measures of the output gap as alternative models. The measures of the output gap are the most arbitrary in the MP models. SPA tests evaluate the effects of the three measures on the evidence of the exchange rate predictability of the linear models. For the precrisis subsample, the results show that models with heterogeneous coefficients, without a constant,

Table 1. Significance of CW tests for models with symmetric Taylor rule

	Homogeneous coefficients												Heterogeneous coefficients											
	Without smoothing						With smoothing						Without smoothing						With smoothing					
	No constant			Constant			No constant			Constant			No constant			Constant			No constant			Constant		
Country	LT	QT	HP	LT	QT	HP	LT	QT	HP	LT	QT	HP	LT	QT	HP	LT	QT	HP	LT	QT	HP	LT	QT	HP
Sample period until June 2008																								
Brazil																				*			**	
Czech Republic				**	**	**				**	**	**	**	**	**	**	**	**	**	**	**	**	*	**
Hungary	**	**	**	**	**	**	**	**	**	*	*	*	**	*	**	**		**	*		*	*		*
Philippines										*		*	**	*	**	*		*	**	*	**	**	*	**
Poland					**	*					*		*	**	*									
South Africa	**	*	**	*	*	**	*	*	**		*	**		*	*		**	**						
Thailand		*			**								*	**		*	**							
Sample period until June 2013																								
Brazil	**													**		*	**		**	***		**	***	
Chile																		*						
Colombia														*	*		*	**						*
Czech Republic														*					*	*		*		
Hungary														**	*					*				
Israel																*								
Mexico													*			*			*					
Philippines			**			**			**	**	**	***			**			**			***			**
Poland													**	**		**	*		**	**		**	**	
South Africa	*													**	*		**	**		*	*		*	*
Thailand		*		*	**						*			**		***	***			**		*	**	

Notes: LT, QT, and *HP* indicate linear trend, quadratic trend, and HP filter, respectively. Blanks mean that the results of the CW tests are insignificant at the 10 percent level of significance. The one-month-ahead CW tests are tests of equal predictive ability with the null hypothesis of a random walk model and the alternative hypothesis of a linear model with Taylor rule fundamentals. The alternative model is the model with symmetric Taylor rule fundamentals either without or with smoothing, estimated with either homogenous or heterogeneous inflation and output coefficients, and either with or without a constant in which potential output are estimated using linear (LT), quadratic (QT), and HP trends. We exclude from Table 1 countries with only insignificant (at the 10 percent level of significance) results of the CW tests for all the models. *Significance level of 10 percent; **significance level of 5 percent; ***significance level of 1 percent. The shaded columns indicate the highest number of rejections at the 10 percent and higher levels of significance among the eight models with the three measures of the output gaps.

Table 2. Significance of CW tests for models with asymmetric Taylor rule

	Homogeneous coefficients												Heterogeneous coefficients											
	Without smoothing						With smoothing						Without smoothing						With smoothing					
	No constant			Constant			No constant			Constant			No constant			Constant			No constant			Constant		
Country	LT	QT	HP	LT	QT	HP	LT	QT	HP	LT	QT	HP	LT	QT	HP	LT	QT	HP	LT	QT	HP	LT	QT	HP
Sample period until June 2008																								
Brazil																				*				
Czech Republic	**	**	**	*		*	**	**	**				**	*	**	*		*	**		**	*		*
Hungary	**	**	**				*	**	*				**		**				*		*			
Korea																					*			*
Philippines							*	*	*	**	**	**	*		*	*		*	**	*	*	**	*	**
Poland		*						*																
South Africa	*	*	**	***	**	***		*	**	**	**	***		**	**	*	**	**			*		*	*
Thailand	*	**											*	**										
Sample period until June 2013																								
Brazil													*	**			**		*	***			**	
Chile															*									
Colombia														*	**			*			*			*
Czech Republic				*						*									*		*			
Hungary				**	**	**				**	**	**												
Korea																	*							
Mexico													*			*								
Philippines			**			**	**	**	***		*	**			**			**			**			*
Poland							*	**	*				**	*					**	**				
South Africa				**		*							*	**	**	**	***	**	*	**	**	*	**	**
Thailand	*	**			*			*					***	***		*	*		*	**				

Notes: *LT, QT*, and *HP* indicate linear trend, quadratic trend, and HP filter, respectively. Blanks mean that the results of the CW tests are insignificant at the 10 percent level of significance. The one-month-ahead CW tests are tests of equal predictive ability with the null hypothesis of a random walk model and the alternative hypothesis of a linear model with Taylor rule fundamentals. The alternative model is the model with asymmetric Taylor rule fundamentals either without or with smoothing, estimated with either homogenous or heterogeneous inflation and output coefficients, and either with or without a constant in which potential output are estimated using linear (LT), quadratic (QT), and HP trends. We exclude from Table 2 countries with only insignificant (at the 10 percent level of significance) results of the CW tests for all the models. *Significance level of 10 percent; **significance level of 5 percent; ***significance level of 1 percent.

Table 3. Significance of the CW tests for models with UIRP, PPP, and monetary fundamentals

	Without constant					With constant				
Country	UIRP	PPP	Money (k = 0)	Money (k = 1)	Money (k = 3)	UIRP	PPP	Money (k = 0)	Money (k = 1)	Money (k = 3)
					Sample period until June 2008					
Brazil							**			
Czech Republic			***	***	***	**	***	**	**	**
Hungary	***		***	***	***		*			
Korea							*			*
Peru					*					
Poland	*		***	***	***	*	**			***
Thailand	*		*	*	*					*
					Sample period until June 2013					
Philippines						*				
Thailand					*				*	*

Notes: LT, QT, and *HP* indicate linear trend, quadratic trend, and HP filter, respectively. The one-month-ahead Clark and West (CW) tests are tests of equal predictive ability with the null hypothesis of a random walk model and the alternative hypothesis of a linear model with fundamentals based on the uncovered interest rate parity (UIRP), purchasing power parity (PPP), and monetary models estimated without or with a constant. The models of monetary fundamentals are estimated with income elasticity, k, equal to zero, one, or three. We exclude from Table 3 countries with only insignificant (at the 10 percent level of significance) results of the CW tests for all the models. *Significance level of 10 percent; **significance level of 5 percent; ***significance level of 1 percent.

and with no smoothing provide the strongest evidence of predictability. We find evidence of predictability in six of thirteen countries: the Czech Republic, Hungary, Philippines, Poland, South Africa, and Thailand. These results confirm the findings of the CW tests shown in the shaded upper middle columns of Table 1. By contrast, the full sample shows evidence of predictability in only four countries: Hungary, Philippines, South Africa, and Thailand. Unlike the CW tests indicated in Table 1, the SPA tests of models with heterogeneous coefficients, without a constant, and with no smoothing cannot reject the benchmark random walk model for Brazil, Colombia, Czech Republic, Mexico, and Poland.

Table 5 shows the significance of the SPA tests with random walk as the benchmark model and heterogeneous Taylor rule specifications without a constant as alternative models. Each of the first four columns shows the p-values of SPA tests with the random walk as the benchmark model against six alternative models. Hence, for the column labeled "Sym" for symmetric, the six alternative models include specifications with smoothing and without smoothing for the three measures of output gap. For the precrisis subsample, the symmetric models reject the random walk model for Czech Republic, Hungary, Philippines, Poland, and Thailand. The asymmetric models reject the random walk for Brazil, Czech Republic, Hungary, Philippines, South Africa, and Thailand.

Between smoothing and no smoothing models, we find stronger evidence of short-term exchange rate predictability for no smoothing models (six rejections of the random walk model) than for smoothing models (four rejections). The last column, labeled "all," shows p-values of SPA tests with twelve alternative models, such as symmetric specification with smoothing and with no smoothing and asymmetric specification with smoothing and with no smoothing, for the three measures of the output gap. The results show evidence of exchange rate predictability in five of thirteen countries—Brazil, Czech Republic, Hungary, Philippines, and Thailand—at the 10 percent and higher levels of significance. Overall, the SPA tests for heterogeneous models without constant show evidence of predictability for Brazil, Czech Republic, Hungary, Philippines, Poland, South Africa, and Thailand in the precrisis subsample. By contrast, for the full sample, the lower half of Table 5 shows significant SPA test results only for Brazil, Hungary, Philippines, South Africa, and Thailand.

Table 4. Significance of tests for superior predictive ability (SPA) for Taylor rule models

	Homogeneous coefficients								Heterogeneous coefficients							
	Without constant				With constant				Without constant				With constant			
	No smoothing		Smoothing		No smoothing		Smoothing		No smoothing		Smoothing		No smoothing		Smoothing	
Country	Sym	Asym	Sym	Asym	Sym	Asym	Sym	Asym	Sym	Asym	Sym	Asym	Sym	Asym	Sym	Asym
Sample period until June 2008																
Brazil											*	**			**	
Czech Republic		**		**	**	*	**		**	**	**	**	**	*	**	
Hungary	**	**	**	**	**		**		**	**	*	*	**		*	
Philippines				*				**	**	*	*	*		*	**	**
Poland		*			*				*							
South Africa	**	**	**	**	**	**	**	**	*	*		*	*	*		
Thailand		**			**				**	**			**			
Sample period until June 2013																
Brazil											**	*			**	
Czech Republic						*										
Hungary						**		**	*							
Philippines	*	**	**	***	**	**	***	**	**	**	**	*	**	*	*	*
Poland				**							*	*				
South Africa						**			*	**		*	**	**		*
Thailand		*			*				*	**			**			

Notes: Blanks mean that the results of the SPA tests are insignificant at the 10 percent level of significance. The significances of the SPA tests are reported for the sixteen Taylor rule specifications, where the null hypothesis is the random walk model and the set of alternatives combines the three output gap measures. The left-hand side of the table reports the significance of SPA tests in which the alternative hypotheses are the homogenous Taylor rule fundamental models where the coefficients on the inflation and output gap are the same in the two countries while the right-hand side of the table reports the significance for heterogeneous Taylor rule models. *Sym* stands for symmetric Taylor rule models; *Asym* stands for asymmetric Taylor rule models. We exclude from the table countries with only insignificant (at the 10 percent level of significance) results of the SPA tests for all the columns. *Significance level of 10 percent; **significance level of 5 percent; ***significance level of 1 percent. The shaded column indicates the highest number of rejections at the 10 percent and higher levels of significance among the 16 models.

Table 5. Significance of SPA tests for heterogeneous Taylor models without constants

Country	Sym	Asym	Smoothing	No smoothing	All
			Sample period until June 2008		
Brazil		*	**		*
Czech Republic	**	**	**	**	**
Hungary	**	**	*	**	**
Philippines	*	*	*	*	*
Poland	*			*	
South Africa		*		*	
Thailand	**	**		**	**
			Sample period until June 2013		
Brazil	*	*	*		*
Hungary	*			*	*
Philippines	**	**	**	**	**
South Africa	*	*	*	*	*
Thailand	*	**		**	**

Notes: Blanks mean that the results of the SPA tests are insignificant at the 10 percent level of significance. The significances of SPA tests are reported for five sets of forecasts based on heterogeneous Taylor rule specifications without a constant. For columns two–five, each column shows test results of the SPA tests with the random walk benchmark against six alternatives; for example, in column two, the six alternatives are the symmetric (Sym) models with and without smoothing and the three measures of the output gap. The last column shows p-values of tests with the random walk benchmark against twelve alternatives: symmetric with smoothing, symmetric with no smoothing, asymmetric with smoothing, and asymmetric with no smoothing for the three output gap measures. *All* stands for all heterogeneous Taylor rule models without a constant; *Sym* stands for symmetric Taylor rule models; *Asym* stands for asymmetric Taylor rule models and Smoothing and No Smoothing are models with and without interest rate smoothing, respectively. We exclude from Table 5 countries with only insignificant (at the 10 percent level of significance) results of the SPA tests for all the columns. *Significance level of 10 percent; **significance level of 5 percent; ***significance level of 1 percent.

Table 6. Significance of SPA tests for non-Taylor rule models

Country	UIRP	PPP	Money
		Sample period until June 2008	
Brazil		***	
Czech Republic	***	***	***
Hungary	***		***
Peru			*
Poland		**	**
		Sample period until June 2013	
None of the countries showed significant results			

Notes: Blanks mean that the results of the SPA tests are insignificant at the 10 percent level of significance. The significance of SPA p-values are indicated for three sets of non-Taylor rule–based forecasts compared with the random walk forecast. Columns two and three show significance of SPA tests of the random walk benchmark against models with uncovered interest rate parity (UIRP) and purchasing power parity (PPP) fundamentals with and without a constant. The last column reports p-values of SPA tests with the random walk as benchmark against six alternatives of monetary models with and without a constant for three different values of k. We exclude from the table countries with only insignificant (at the 10 percent level of significance) results of the SPA tests for all the columns. *Significance level of 10 percent; **significance level of 5 percent; ***significance level of 1 percent.

The results of the SPA tests reported in the upper half of Table 6 indicate the following for the precrisis subsample. Models based on UIRP outperform the random walk for Czech Republic and Hungary; models based on PPP outperform the random walk for Brazil, Czech Republic, and Poland; and models based on monetary fundamentals outperform the random walk for Czech Republic, Hungary, Poland, and Peru. However, the lower half of Table 6 shows that for the full sample, there is no evidence of exchange rate predictability in non-Taylor rule models.

Following Molodtsova and Papell (2009), in Figure 1 we plot the changes of the coefficients of Equation (3) over time for currencies of seven emerging countries for which the symmetric Taylor rule model yields significant evidence of exchange rate predictability in Table 5. The Taylor rule specifies

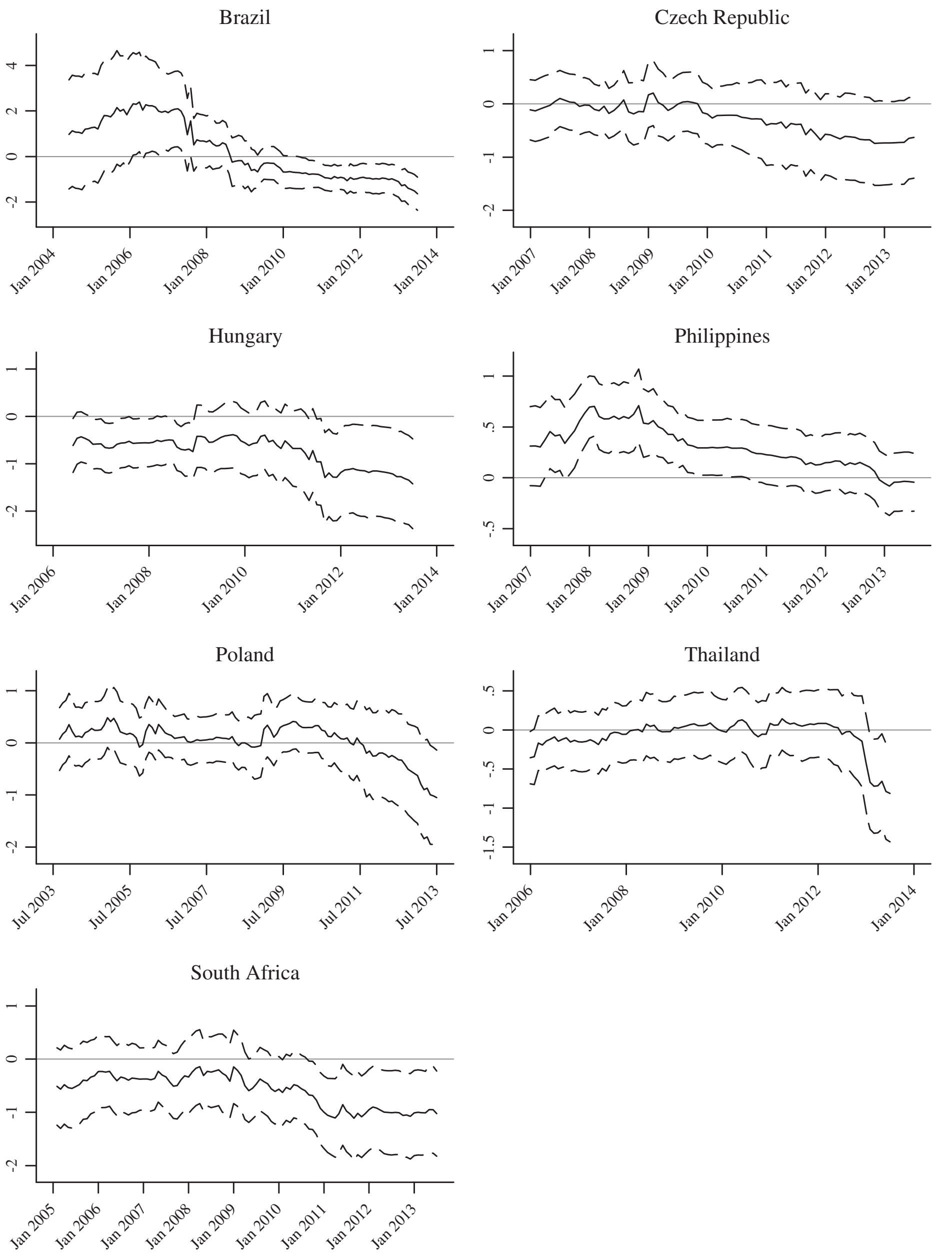

Figure 1. Coefficients on U.S. inflation.

that the central bank should raise interest rates when inflation rises, which strengthens the country's currency. Figure 1 shows the plots of coefficients on U.S. inflation with 90 percent confidence intervals beginning five years—the span of the rolling window—after the adoption of inflation targeting. The plots for Brazil, Hungary, and South Africa support the Taylor rule. The coefficients on U.S. inflation are close to zero at the beginning of the forecast period but become negative and significant from the middle to the end of the forecast period. A rise in U.S. inflation thus causes appreciation of the U.S. dollar. Czech Republic, Poland, and Thailand show more limited evidence in favor of the Taylor rule. However, the coefficients for Philippines do not support the Taylor rule.

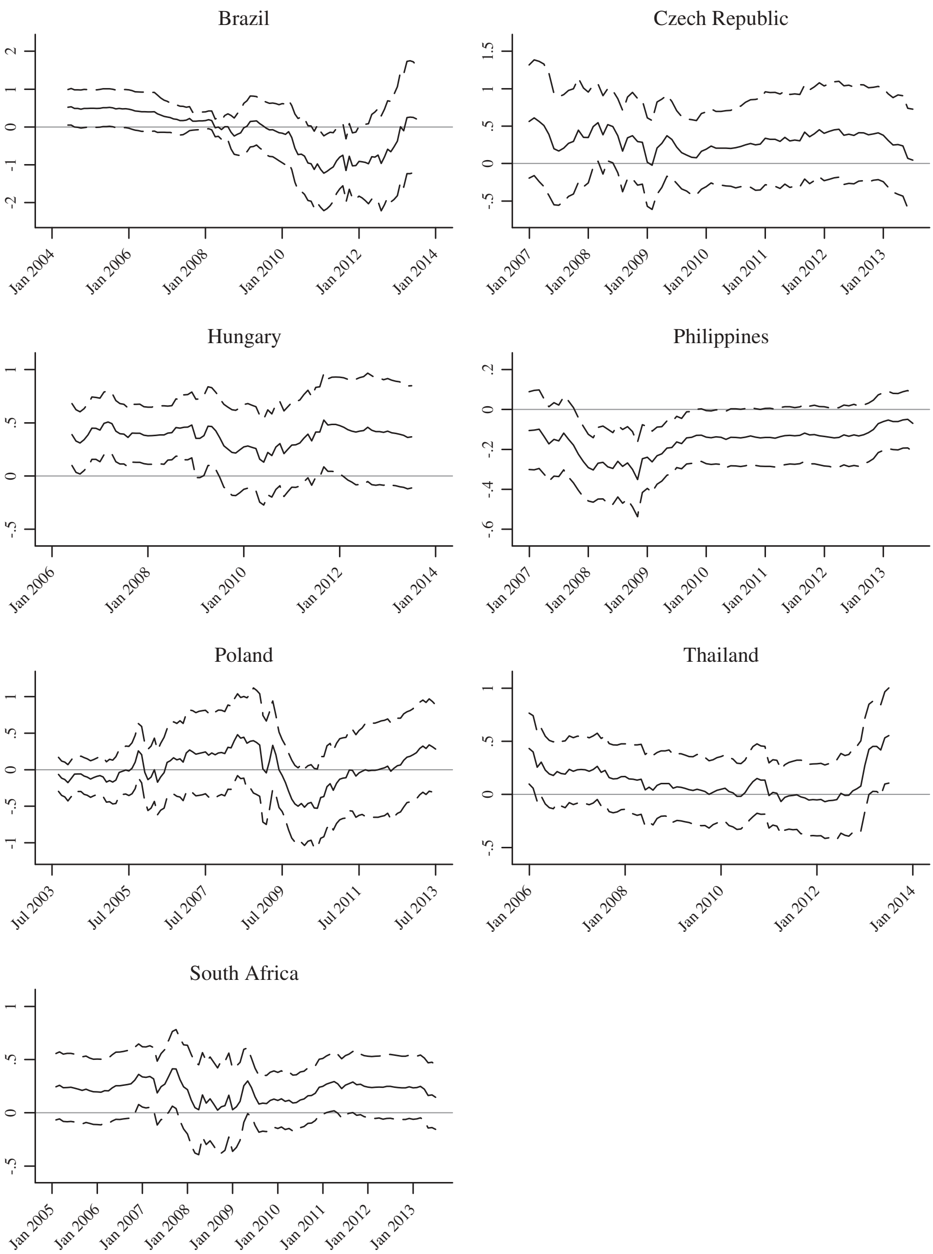

Figure 2. Coefficients on domestic inflation.

Figure 2 plots the coefficients on domestic inflation. The plots show the coefficient values are positive and significant until the middle of the forecast period for Hungary. This means the Hungarian currency appreciates when the Hungarian inflation rate rises, which is consistent with the Taylor specification. The coefficients for Brazil, Czech Republic, Poland, and South Africa are insignificant and close to zero. For Thailand, the coefficients are close to zero but turn positive and significant at the end of the period. By contrast, the coefficients for the Philippines are initially close to zero but turn negative and then close to zero again.

Concluding Observations

While there is a large empirical literature that examines the out-of-sample predictability of the exchange rates of advanced economies, the literature that looks at the issue for emerging countries is relatively thin. We apply Molodtsova and Papell's (2009) rigorous analysis to thirteen inflation-targeting emerging countries in Africa, Asia, and Latin America. We find some, but not overwhelming, evidence of out-of-sample exchange rate predictability for models based on Taylor rule fundamentals.

We find evidence of exchange rate predictability of Taylor rule models using the CW tests in eight countries for the precrisis subsample period until 2008 and in eleven countries for the full sample period until 2013. While the SPA tests confirm the evidence of predictability of the Taylor rule models in seven countries for the precrisis subsample, they confirm predictability in only seven countries for the full sample. Similarly, we find evidence of exchange rate predictability using the CW tests for models based on monetary fundamentals, UIRP, and PPP in seven countries for the precrisis subsample and in two countries for the full sample. However, the SPA tests confirm predictability in only five countries in the precrisis subsample and none for the full sample.

Such results contrast with those of Molodtsova and Papell (2009), who are able to confirm the results of the CW tests with the SPA tests for advanced economies. Therefore, our evidence suggests that SPA tests may be even more important for emerging countries in the analysis of exchange rate predictability. In particular, SPA tests reduce the possibility of data snooping with a large number of alternative models and testable hypotheses. Our analysis of exchange rate predictability in thirteen inflation-targeting emerging countries in the precrisis subsample period and full sample period indicates that conducting SPA tests improves the robustness of analysis across different sample periods. Our robust results differ from those of Rossi (2013), who finds that evidence of predictability for advanced economies is not robust across different sample periods.

Among the seven countries that show some evidence of exchange rate predictability using the Taylor rule, the direction of exchange rate forecasts is consistent with the Taylor rule for most countries for some of the forecast periods. However, the Philippines is an exception, with the forecasted U.S. dollar–Philippine peso exchange rate moving opposite to the direction predicted by the Taylor rule. Therefore, in analyzing the predictability of exchange rates in emerging markets, it is important to determine the direction of exchange rate forecasts in Taylor rule–based models.

Notes

1. Rossi (2013) reviews the literature on predictability of exchange rates in developed countries. She notes that the evidence of predictability of exchange rates of developed countries depends on, among others, differences in the models, the tests of predictability, the span of the data, and the period of the sample. However, she finds no significant difference in the results of the predictability of exchange rates between studies that use monthly data and those that use quarterly data.

2. The fifteen emerging countries are Brazil, Chile, Czech Republic, Colombia, Hungary, Israel, Korea, Mexico, Peru, Philippines, Poland, Romania, South Africa, Thailand, and Turkey.

3. The nonpoolability of sample of emerging countries is not surprising considering that these countries vary a great deal in terms of income and development level, economic structures, and monetary policy. See, for example, Aizenman et al. (2010) and Rossi (2013).

4. Our focus is on the predictability of exchange rates in emerging countries using economic models including the Taylor specification. Related literature uses the modified Taylor rule specification to examine monetary policies in emerging countries including the role of real exchange rates in emerging countries. Please refer to Aizenman et al. (2010) for a brief review of the literature.

5. In contrast to Galimberti and Moura (2013), we exclude Romania and Turkey, which were excluded by Gonçalves and Salles (2008) and Siklos (2008) as inflation-targeting emerging countries.

6. Our study is not directly comparable to Galimberti and Moura (2013) and Moura (2010) because they use error correction models and different periods and spans of data. Galimberti and Moura (2013) use panel methods and quarterly data. Moura (2010) also considers these models in the EC framework and finds limited evidence of predictability for monetary models for Chile, Mexico, and Peru; the PPP model for Chile and Colombia; and UIRP for Brazil, Chile, and Mexico; but mostly for forecasting horizon over one month. Nevertheless, we go beyond these three studies in conducting tests to guard against data snooping (the tests of superior predictive ability [SPA]) and in examining the evolution of the forecast coefficients of the Taylor equations to examine consistency with the Taylor principles.

7. The bilateral U.S. real exchange rate, q, is equal to the log (U.S. dollar exchange rate per foreign currency) + log (foreign country CPI) – log (U.S. CPI).

8. Taylor (1993) assumes that $\varphi = \gamma = 0.5$ and $\bar{\pi}_t = \bar{r} = 2\%$ in which the central bank raises the target interest rate when $\pi_t > \bar{\pi}_t$ and/or $\widehat{y}_t > 0$.

9. Molodtsova and Papell (2009) note the findings in the empirical literature that the UIRP does not hold (e.g., Chinn 2006; Gourinchas and Tornell 2004). Hence, contrary to UIRP, Molodtsova and Papell (2009) reverse the signs in Equation 2 to derive Equation 3. Please refer to Molodtsova and Papell (2009) for the details.

10. In emerging economies, the policy short-term interest rates may not be represented by the market interest rates relevant to exchange rates particularly since financial markets may not be as deep or liquid as advanced economies. A direct implication may be a weak link between interest rates and exchange rates resulting in the smoothing parameter being mostly insignificant. Therefore, the "no smoothing" parameter may not necessarily reflect the smoothing or no-smoothing behavior of central banks in emerging countries. It could also affect the other variables on the right-hand side of Equation 3 so the null hypothesis random walk without drift could not be rejected using the CW and SPA tests.

11. The inflation-targeting (IT) countries and the implementation dates are as follows: Brazil (June 1999), Chile (September 1999: late implementation date), Colombia (January 1999), Czech Republic (January 2002), Hungary (June 2001), Israel (June 1997:06: late implementation date), Korea (April 1998), Mexico (January 2001: late implementation date), Peru (January 2002), Philippines (January 2002), Poland (September 1998), South Africa (February 2000), and Thailand (May 2000). The implementation dates are from Truman (2003).

12. The production or manufacturing indexes for Brazil, Chile, Colombia, Hungary, Mexico, Peru, Philippines, and Thailand were not seasonally adjusted, so they were seasonally adjusted using the X11 command in RATS. It assumes multiplicative seasonal factor. Moura (2010) and Moura and Carvalho (2010) use industrial production index as a proxy for output and estimate the output gaps using the HP filter.

13. Nikolsko-Rzhevskyy (2011) points out that the procedure of extending the HP trend six months ahead to t+5 and using the HP trend at t as the value of the one-period-ahead forecast of potential output eliminates the possible end-of-sample bias in calculating the one-period-ahead forecast of potential output using HP trend. In contrast to Molodtsova and Papell (2009), who use all past data to construct potential output, we use rolling regressions with a twenty-four-period rolling window because the plots of the thirteen countries' IPI or MPI show higher volatility than U.S. IPI with what seem to be two large breaks from the late 1990s to 2011. As noted in Eklund et al. (2010), we could expect regressions with short rolling windows to perform well when a series have large breaks. However, the performance could deteriorate as the size of the breaks declines. The choice of a twenty-four-period rolling window in calculating potential output is due to the relatively small size of our sample.

14. According to Molodtsova and Papell (2009), tests of equal predictability of two nonnested models, developed by Diebold and Mariano (1995) and West (1996) (DMW), are often used to assess the out-of-sample performance of models by comparing their MSPEs. However, in testing the out-of-sample predictability of exchange rates, the null is random walk, so it would be nested into any fundamental-based model. Application of the DMW procedure on nested models results in tests that are undersized and with low power. Kilian (1999) and Mark (1995) overcome the problems associated with applying the DMW procedure on nested models by calculating bootstrapped critical values. Molodtsova and Papell (2009) argue that while bootstrapping solves the problems of using the DMW test in nested models, the CW test has greater power than the DMW test.

15. We set the rolling window in the rolling regression to sixty periods because of data limitations.

16. Clark and West (2006) show that the CW test has lower power and is slightly undersized when rolling windows and predictive periods are shorter.

17. Alba and Wang (2014) show that after 2008, the Taylor rule does not hold for the United States.

18. Tables 1 and 2 show two models with fourteen cases of CW tests that are significant for symmetric Taylor rule models with heterogeneous coefficients, without smoothing and with a constant (lower right middle columns of Table 1) and for asymmetric Taylor rule models with heterogeneous coefficients, without smoothing and with

no constant (lower middle columns of Table 2). However, Hansen's SPA tests in Table 4 confirm less evidence of exchange rate predictability in these models than the symmetric Taylor rule models with heterogeneous coefficients, without smoothing and with no constant.

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References

Aizenman, J.; M. Hutchison; and I. Noy. 2010. "Inflation Targeting and Real Exchange Rates in Emerging Markets." *World Development* 39, no. 5: 712–724.

Alba, J.D., and P. Wang. 2014. "Taylor Rules and Discretionary Regimes in the United States: Evidence from a K-State Markov Regime Switching Model." Manuscript. Nanyang Technological University.

Cheung, Y.-W.; M.D. Chinn; and A.G. Pascual. 2005. "Empirical Exchange Rate Models of the Nineties: Are Any Fit to Survive?" *Journal of International Money and Finance* 24, no. 7: 1150–1175.

Chinn, M.D. 2006. "The (Partial) Rehabilitation of Interest Rate Parity in the Floating Rate Era: Longer Horizons, Alternative Expectations, and Emerging Markets." *Journal of International Money and Finance* 25, no. 1: 7–21.

Clark, T.E., and K.D. West. 2006. "Using Out-of-Sample Mean Squared Prediction Errors to Test the Martingale Difference Hypothesis." *Journal of Econometrics* 135, no. 1–2:155–186.

———. 2007. "Approximately Normal Tests for Equal Predictive Accuracy in Nested Models." *Journal of Econometrics* 138, no. 1: 291–311.

Diebold, F.X., and R.S. Mariano. 1995. "Comparing Predictive Accuracy." *Journal of Business and Economic Statistics* 13, no. 3: 253–263.

Eklund, J.; G. Kapetanios; and S. Price. 2010. "Forecasting in the Presence of Recent and Recurring Structural Change." Working Paper no. 406, Bank of England, London.

Galimberti, J.K., and M.L. Moura. 2013. "Taylor Rules and Exchange Rate Predictability in Emerging Countries." *Journal of International Money and Finance* 32, no. 1: 1008–1031.

Gonçalves, C.E.S., and J.M. Salles. 2008. "Inflation Targeting in Emerging Economies: What Do the Data Say?" *Journal of Development Economics* 85, no. 1–2:312–318.

Gourinchas, P.-O., and A. Tornell. 2004. "Exchange Rate Puzzles and Distorted Beliefs." *Journal of International Economics* 64, no. 2: 303–333.

Hansen, P.R. 2005. "A Test for Superior Predictive Ability." *Journal of Business and Economic Statistics* 23, no. 4: 365–380.

Hodrick, R.J., and E.C. Prescott. 1997. "Postwar U.S. Business Cycles: An Empirical Investigation." *Journal of Money, Credit, and Banking* 29, no. 1: 1–16.

Kilian, L. 1999. "Exchange Rates and Monetary Fundamentals: What Do We Learn from Long-Horizon Regressions?" *Journal of Applied Econometrics* 14, no. 5: 491–510.

Kim, H., and D. Ryu. 2014. "Forecasting Exchange Rate from Combination Taylor Rule Fundamental." *Emerging Markets Finance & Trade* 49, supp. 4: 81–92.

Mark, N.C. 1995. "Exchange Rate and Fundamentals: Evidence on Long-Horizon Predictability." *American Economic Review* 85, no. 1: 201–218.

———. 2009. "Changing Monetary Policy Rules, Learning, and Real Exchange Rate Dynamics." *Journal of Money, Credit and Banking* 41, no. 6: 1047–1070.

Meese, R.A., and K. Rogoff. 1983. "Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?" *Journal of International Economics* 14, no. 1–2: 3–24.

Molodtsova, T., and D.H. Papell. 2009. "Out-of-Sample Exchange Rate Predictability with Taylor Rule Fundamentals." *Journal of International Economics* 77, no. 2: 167–180.

Moura, M.L. 2010. "Testing the Taylor Model Predictability for Exchange Rates in Latin America." *Open Economies Review* 21, no. 4: 547–564.

Moura, M.L., and A. de Carvalho. 2010. "What Can Taylor Rules Say About Monetary Policy in Latin America?" *Journal of Macroeconomics* 32, no. 1: 392–404.

Nikolsko-Rzhevskyy, A. 2011. "Monetary Policy Evaluation in Real Time: Forward-Looking Taylor Rules Without Forward-Looking Data." *Journal of Money Credit and Banking* 43, no. 5: 871–897.

Rossi, B. 2013. "Exchange Rate Predictability." *Journal of Economic Literature* 51, no. 4: 1063–1119.

Siklos, P. 2008. "Inflation Targeting Around the World." *Emerging Markets Finance & Trade* 44, no. 6: 17–37.

Taylor, J.B. 1993. "Discretion Versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy* 39: 195–214.

Truman, E.M. 2003. *Inflation Targeting in the World Economy.* Washington, DC: Peterson Institute.

West, K.D. 1996. "Asymptotic Inference About Predictive Ability." *Econometrica* 64, no. 5: 1067–1084.