+

UNIVERSITY OF THE WITWATERSRAND

Exchange Rate Forecasting Using Uncovered Return Parity

by

Michael M Ncube

Supervisor

Professor: Christopher Malikane

Abstract

This paper presents a unified exchange rate model of exchange rate determination and forecasting using the Monteary Fundamentals, the Taylor Rule Fundamentals as well as the return differentials of a portfolio composed of money market instruments, bonds, and equity market returns. We use the simple OLS estimation technique for the estimation and a recursive rolling regression technique to generate the out-of-sample forecasts. The out-of-sample forecast analysis, using the Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), Mean Squared Prediction Error (MSPE), and the Theil U2 coefficient statistic for model statistic suggests that our unified forecasting exchange rate model outperforms the naïve random walk model in forecasting one-month nominal exchange rates for all the countries in the study. The results also show that the unified forecasting exchange rate model is also able to outperform the Taylor Rule Fundamentals for 13 out of 14 of the countries at one month ahead forecasting horizon. These findings imply that the combination of the Taylor Rule Fundamentals, as well as the three market variables in modelling exchange rates, improves the forecasting ability of exchange rate models.

Acknowledgements

I would like to thank my supervisor, Prof. Christopher Malikane for his help during the initial phases of this research. His inputs on both the content of this document, as well as background in the area have been of great help and are much appreciated.

I would also like to thank my family, especially my Parents and colleagues – Patricia Ncube, Mandla Ncube and Tamzin Stroucken - for their unconditional support and unwavering faith in my abilities. It is a blessing to be surrounded by such remarkable people. Lastly, my thanks also go to my friend Thabo Molefe for being there to assist whenever I needed help with the class materials or clarification of some notions concerning this research.

Contents

List of Tables

Chapter 1

Introduction

1.1 Background

Exchange rates play a vital role in global finance and trade. Investors seek profits by investing internationally, but they face exchange rate risks. These rates also impact how money flows between countries and affect investment choices. Researchers have studied exchange rates extensively, starting from the Bretton Woods period. Meese and Rogoff (1983) questioned traditional theories' ability to predict rates and introduced the Meese-Rogoff puzzle, which favored the random walk model over fundamental methods. Cheung et al. (2005) found that common prediction models didn't consistently beat basic random walk models. Yet, Mark (1995) and Mark and Sul (2001) challenged this, showing that fundamental factors can indeed predict long-term exchange rate movements.

Recent research by Molodtsova and Papell (2009) demonstrated that Taylor rule fundamentals significantly outperform the random walk model in predicting future outcomes, as assessed using the Clark and West (2006) test. Engle (2019) also found that incorporating uncovered interest parity, especially in the context of Taylor rule fundamentals, enhances exchange rate forecasting accuracy. This recent literature collectively supports the superiority of including Taylor Rule fundamentals in exchange rate prediction models over-relying on the random walk model.

Djeutem and Dunbar (2022) discovered that expected asset returns, regardless of exchange rate direction, may better explain exchange rate behavior. They propose that stock market returns could offer a more plausible explanation for exchange rate movements, supported by prior research like Hau and Rey (2006) and Curcuru et al. (2014). This study aims to assess if a model considering a broader range of return differences outperforms the Meese and Rogoff random-walk model and if it surpasses Engle's (2019) exchange rate forecasting model based solely on Taylor rule fundamentals.

The remainder of this paper is organized as follows. In the next chapter, we will provide a brief review of the existing literature on exchange rate determination and forecasting. This will help us to understand the background and context of our study. It will also delve into empirical exchange rate models and explain their underlying principles and theories. In Chapter 3 we will outline our forecasting model. In Chapter 4, we describe the data sources. In Chapter 5, we outline our measures of performance evaluation while Chapter 6 presents the findings and results obtained from our analysis, shedding light on the patterns and relationships discovered. Finally, in Chapter 7, we draw conclusions based on the findings and discuss their implications for the field of exchange rate forecasting.

1.2 Significance of the topic

We find the current study significant as it provides evidence of the determination and forecasting of the exchange rates. The proposed model can be used by financial institutions, policymakers and in particular investors who are exposed to currency risk.

When making investment decisions in foreign markets, investors consider not only interest rate differentials but also potential returns from various assets like money markets, stock markets, and bond markets. This approach, as suggested by Djeutem and Dunbar (2022), Klein and Shambaugh (2010), and Hakkio and Rush (1991), accounts for stable exchange rates and investors' tendency to allocate more funds to markets with anticipated positive stock market performance, influencing currency appreciation. Therefore, adopting a model that includes return variations is crucial for exchange rate forecasting, offering a deeper understanding of currency value determinants.

1.3 Research problem

Engle (2019) criticized the reliance on Taylor Rule (TR) fundamentals for exchange rate forecasts. He emphasized that including an inflation variable, instead of the interest rate differential, provides more accurate predictions. He found that high U.S. inflation in one month can forecast the dollar's performance in the following month. Engle's critique also highlighted that funds do not move based solely on interest rate differentials. To address this, he proposed a model that considers a wider range of asset returns. This broader approach offers a more comprehensive understanding of how numerous factors influence fund movements.

between economies.

1.4 Research question

While there appears to be a consensus that TR-based models best forecast exchange rates, our research aims to address the following question:

- Does a forecasting model that incorporates a broader concept of return differentials demonstrate superior performance compared to the random walk?
- Does a forecasting model that incorporates a broader concept of return differentials

demonstrate superior performance compared to existing exchange rate forecasting models based solely on Taylor rule fundamentals?

1.5 Contribution of the research

Our study seeks to enhance exchange rate forecasting by introducing a model that considers a wider range of return differentials. In contrast to existing models that concentrate on short- term interest rates, we expand our approach to encompass returns from stocks and bonds. Moreover, we incorporate Taylor rule fundamentals to understand interest rate variations better. Through this analysis, we aim to advance the understanding of exchange rate forecasting methods and highlight the benefits of including a wider range of return differences for better predictive accuracy.

1.6 The gap in the literature

Existing literature has extensively examined the effectiveness of various models in exchange rate forecasting. Among these models, the use of Taylor rule fundamentals has demonstrated superior performance compared to alternative approaches. However, limited research has been conducted to assess whether a model based on a wider range of return differentials outperforms the Taylor rule fundamentals-based model. Consequently, our objective is to address this research gap by investigating the potential advantages of employing a return differential-based model in exchange rate forecasting. This study builds on the works of Djeutem and Dunbar (2022), Hau and Rey (2006), and Curcuru et al. (2014), who have highlighted the importance of considering broader return differentials in understanding exchange rate movements.

Chapter 2

Model

In this section, we examine different models and influential factors in exchange rate forecasting. Meese and Rogoff's (1983) examination of economic models compared to the random walk model serves as a foundational point. Their findings questioned the effectiveness of monetary basics in forecasting and raised issues related to unexpected factors and limited data. Additionally, we explore the Taylor Rule Fundamentals, supported by Molodtsova and Papell's (2009) research. Which showed significant improvements in predictive accuracy compared to the random walk model. Engle's (2019) findings further emphasize the importance of the Taylor Rule in forecasting exchange rates, especially for short-term predictions. Lastly, we examine the Uncovered Return Parity Condition, building on previous studies and highlighting their relevance in understanding how exchange rates behave.

2.1 Random Walk

Meese and Rogoff (1983) focused on how well economic models using monetary basics could predict future exchange rates. They compared these models to a simple random walk model. In their research, Meese and Rogoff tested different ways to predict exchange rates using examples of future situations. They found that even though complicated economic models were used, the random walk model often gave forecasts that were just as good or sometimes even better.

They specified that the dynamics of exchange rate returns are driven by the following regression:

$$\Delta e_{t+1} = \alpha_0 + \epsilon_t \tag{1}$$

The first specification is the random walk (RW) model. This model has been the standard benchmark in the literature on exchange rate predictability since the seminal work of Meese.and Rogoff (1983). We adopted the random walk with drift model as specified by Della Corte et al. (2008). The model indicates a direct relationship between et and α0.

Meese and Rogoff's study found that there were different reasons why exchange rates did not match up with economic fundamentals. They thought this could be due to problems like unexpected oil price changes, issues with predicting certain factors and having a small amount of data to work with. Other studies tried to solve this puzzle by giving ideas about how to connect exchange rates with economic basics. For instance, Engel and West (2005) showed that exchange rates can follow certain patterns and become more unpredictable when a specific factor gets closer to a certain number. Engel and West (2006) made a model that explained that the difference between real exchange rates from their usual state depends on a mix of inflation and economic output differences. They discovered a link between these factors for the actual dollar-euro exchange rate.

2.2 Monetary Fundamentals

Based on the monetary model of determining exchange rates, changes in the value of one country's money compared to another's should show how their money, economic activity, interest rates, and prices are moving. This model, introduced by Frenkel (1976) and Mussa (1976), builds on an idea where the amount of goods a country makes is set and real money demand depends on how much people make and the interest rate. If we use exchange rates to talk about interest rates and prices, we can connect them to money and economic activity.

For our analysis we adopt the flexible-price monetary model from the 1970s as a representative example. This model views the exchange rate as a relative price between two currencies and explains exchange rate dynamics based on the relative demand for and supply of money in both countries. The long-term equilibrium in the money markets of both the domestic and foreign countries is described as follows:

$$m_t = p_t + \beta z_t - h i_t \tag{2}$$

$$m_t^* = p_t^* + \beta^* z_t^* - h^* i_t^* \tag{3}$$

Where $\mathrm{m_t}, \mathrm{p_t}$ and $\mathrm{z_t}$ are the logs of money supply, price level and income and $\mathrm{i_t}$ is the level of interest rate in period t. while the asterisks denote the foreign country variables.

Additionally, the monetary fundamentals incorporate a fixed value of income elasticity denoted below as k.

Consequently, the change in exchange rate is therefore derived as:

$$\Delta e_t = (m_t - m_t^*) - k(z_t - z_t^*) \tag{4}$$

Here, Δe_t, represents the change in the exchange rate over time t.

Despite the theoretical framework, empirical studies have questioned the predictive power of this model. Meese and Rogoff (1983a, 1983b) found that a simple random walk often outperformed this model in forecasting future exchange rates. Chinn and Meese (1995) echoed this sentiment for short-term predictions, while Cheung et al. (2005) argued that the model's limitations extend even to long-term forecasts. Conversely, Mark (1995) found compelling evidence supporting the model for very long-term predictions. However, studies by Berkowitz and Giorgianni (2001), Kilian (1999), Groen (1999), Faust, Rogers, and Wright (2003), and Rossi (2005c) suggested that the model does not consistently provide accurate forecasts, particularly over extended periods.

On the other hand, Cheung et al. (2005) delved into the practical performance of various exchange rate models. They took a closer look at models centered around interest rates, money, productivity, and behavior. Interestingly, their findings revealed that none of these models consistently outperformed a simple random guess when it came to predicting exchange rates across different timeframes. This conclusion supported the discoveries of Kilian (1999), Berben and van Dijk (1998), Bacchetta and Wincoop (2010), Berkowitz and Giorgianni (2001), and Mark and Sul (2001). These earlier studies collectively found that relying solely on monetary factors offered limited predictive capabilities when it comes to long-term exchange rate forecasts.

2.3 Taylor Rule Fundamentals

Molodtsova and Papell (2009), examined the effectiveness of Taylor rule fundamentals in predicting exchange rates. Their research demonstrated that the Taylor rule fundamentals showed significantly improved predictive accuracy when compared to the random walk model. This assessment was supported by the utilization of the Clark and West (2006) test, a method for contrasting model predictions using real-world data not previously employed.

Overall, their findings suggest that incorporating Taylor rule-related factors, such as central bank interest rate decisions, holds promise for enhancing the precision of exchange rate forecasts.

The Molodtsova and Papell (2009) (MP) models specify Taylor's monetary policy rules incorporating bilateral real exchange rate, q, as

$$i_t = \pi_t + \emptyset\ (\pi_T - \pi^*) + \gamma \overline{y_t} + \ddot{r} + \delta q \tag{5}$$

Where i_t is the short-term nominal interest rate target, π_t is the inflation rate, π^* is the target level of inflation, $\overline{yt}$ is the output gap or the percent deviation of actual from potential output, $\ddot{r}$ is the equilibrium real interest rate and q is the real exchange rate.

To account for partial adjustment in interest rates, Molodtsova and Papell (2009) suggest:
$i_t = (1 - \rho)\ \overline{\imath_t} + \rho i_{t-1} + v_t$

In this case, ρ is the adjustment coefficient, and then derived the forecasting equation between the United States and the foreign country as follows:

$$i_t - i_t^* = \alpha + \alpha_{u\pi}\pi_t - \alpha_{f\pi}\pi_t^* + \alpha_{uy}\hat{y}_t - \alpha_{fy}\hat{y}_t^* - \alpha_r r_t^* + \rho_u i_{t-1} - \rho_f i_{t-1}^* + n_t \tag{6}$$

Where i_t^* nominal interest rate for a foreign country, while $\hat{y}_t^*$ is the output of the foreign country. Notably, α and other coefficients reflect the sensitivity of interest rates to inflation and output gaps for both the U.S. and foreign counties.

Molodtsova and Papell (2009) equate the interest differential to $i_t - i_t^*$ expected change in the nominal exchange rate Δe_{t+1} (where e is the log of U.S. dollars per unit of foreign currency) in Equation (4) but reverse the signs for consistency with the findings of the empirical literature, which suggests that an increase in the interest rate differential is associated with a forecasted depreciation of the exchange rate, contrary to the predictions of uncovered interest rate parity (UIRP). Therefore, the relationship can be expressed as:

$$\Delta e_{t+1} = \omega - \omega_{u\pi}\pi_t + \omega_{f\pi}\pi_t^* - \omega_{uy}y_t + \omega_{fy}y_t^* + \omega_r r_t^* - \omega_{ui}i_{t-1} + \omega_{fi}i_{t-1}^* + \varepsilon_t \tag{7}$$

The coefficients in Equation (7) 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.

Additionally, Engle (2019) found that the Taylor rule helps decide how much interest rates change based on factors like inflation and the gap between actual and potential economic output. The study found that using the Taylor Rule Fundamentals can help predict exchange rates more accurately. This improved prediction even works well for short periods, like one month. In simpler terms, considering the Taylor rule factors seems to be a better way to forecast how exchange rates will change compared to just a random walk and a monetary model.

Similarly, Engel and West (2005) delved into how monetary policy with other factors impacts exchange rates. Their approach did not isolate exchange rates but also factored in the influence of interest rates, providing a perspective on understanding exchange rate behavior. Their findings align with similar studies, such as Mark's (2009) exploration of an alternative Taylor rule, which linked interest rates to exchange rates and yielded positive results. Additionally, researchers like Waldman and Clarida (2008) and Wang and Wu (2008) found favorable outcomes when examining various forms of the Taylor rule in relation to exchange rates. These collective studies have significantly enhanced our comprehension of the relationship between Taylor Rule fundamentals and exchange rates.

2.4 The Uncovered Return Parity Condition

The Uncovered Return Parity (URP) condition examines the relationship between asset prices and exchange rates. Hau and Rey (2006) introduced a significant concept linking exchange rates to performance differentials in equity markets. They posited that when investors from one country realize profits from investments in another country's stock market, they are likely to reinvest these earnings, thereby strengthening their domestic currency. This idea underscores the dynamic interplay between equity performance and currency valuations. Supporting this perspective, Curcuru et al. (2014) provided empirical evidence demonstrating that equity returns significantly influence currency valuations, showing that higher returns in a country’s equity market can attract foreign investment, leading to currency appreciation.

In this paper, we develop a model that integrates expected changes in exchange rates with anticipated return differentials across money markets, equities, and bonds in the U.S. market.

2.4.1 Differentials on money markets (Treasury Bills)

$$\Delta i_t = \hat{\alpha} + \alpha_i(i_{t-1} - i^*_{t-1}) \qquad (8)$$

Where i_t is the logarithm of treasury bill return, α is a constant, i_{t-1}) is the money market differential of the domestic currency, while i^*_{t-1} is the money market differential of the foreign currency.

Equation (8) captures changes in treasury bill returns by accounting for the difference between domestic and foreign money market differentials, highlighting how variations in these differentials influence short-term interest rate differentials. Menkhoff et al. (2012) explored this relationship and found that shifts in interest rates across countries can predict currency movements, indicating that changes in treasury yields play a crucial role in exchange rate dynamics.

2.4.2 Differentials on interest rates

$$\Delta R_t = \hat{\alpha} + \alpha_R \, (R_{t-1} - R^*_{t-1}) \qquad (9)$$

Where Rt is the logarithm of a long-term bond return, α is a constant, R_{t-1} is the bond market differential of the domestic currency, while R^*_{t-1} is the bond market differential of the foreign currency.

Equation (9) models change in long-term bond returns while considering disparities between domestic and foreign bond market differentials. Fama and Bliss (1987) demonstrated that the term structure of interest rates carries significant information about future economic conditions, suggesting that long-term bond returns can also impact currency valuations through their influence on investor expectations.

2.4.3 Differentials on equity returns.

$$\Delta_q = \hat{\alpha} + \alpha_q \left(\Delta_{qt-1} - \Delta^*_{qt-1}\right) \tag{10}$$

Where Δ_q is the logarithm of the domestic equity market return, α is a constant, Δ_{qt-1} is the domestic equity market differential of the domestic currency, while Δ^*_{qt-1} is the equity market differential of the foreign currency.

Equation (10) elucidates changes in domestic equity market returns, considering the differences between domestic and foreign equity market differentials. Kasa (1992) found that common stochastic trends in international stock prices imply that fluctuations in equity markets across countries are interconnected, which can significantly affect exchange rate dynamics.

Combining these equations yields the following URP equation:

$$\Delta e_t = \alpha_0 + \beta_0(i_{t-1} - i^*_{t-1}) + \beta_1(R_{t-1} - R^*_{t-1}) + \beta_2\left(\Delta_{qt-1} - \Delta^*_{qt-1}\right) + \varepsilon_t \tag{11}$$

In this equation, Δe_t represents the change in the exchange rate, while the coefficients β_0, $\beta_{1,}$ and β_2 capture the influence of respective differentials on the exchange rate. This unified regression equation integrates the dynamics of treasury bill returns, long-term bond returns, and equity returns, incorporating constant terms and differentials.

Djeutem and Dunbar (2018) also found that that investors frequently base their fund allocation decisions on the performance of various assets relative to interest rates. Their findings indicate that shifts in asset performance directly influence investment strategies, emphasizing the importance of understanding how equities, bonds, and money market returns impact investor behavior. Similarly, Gyntelberg et al. (2018) investigated the interplay between trading in foreign exchange, bonds, and equities, concluding that foreign investors' activities in local stock markets significantly influence exchange rates. This further illustrates the interconnectedness of asset markets and currency valuations, showing that capital flows driven by asset performance can create ripple effects in exchange rate movements.

Chapter 3

3.1 Theoretical derivation of the model

The problem we are aiming to solve is whether a forecasting model that incorporates a wider range of return differentials can yield better results as compared to the model proposed by Engle (2019. Our broader model will include the Taylor Rule Fundamentals, Monetary Fundamentals and Uncovered Interest Rate Parity (URP). Each model contributes different economic factors to the unified forecasting model.

We can now assemble the variables and coefficients of the Monetary Fundamentals in equation 4, the Taylor Rule Fundamentals in equation 8, and the Uncovered Return Parity (URP) in equation 11 into a unified exchange rate forecasting model:

$$\Delta e_{t+1} = \alpha_0 + \beta_0\left(\omega_{u\pi}\pi_t + \omega_{f\pi}\pi_t^* - \omega_{uy}y_t + \omega_{fy}y_t^* + \omega_r r_t^* - \omega_{ui}i_{t-1} + \omega_{fi}i_{t-1}^*\right) + \beta_1(i_{t-1} - i_{t-1}^*) + \beta_2(R_{t-1} - R_{t-1}^*) + \beta_3\left(\Delta_{qt-1} - \Delta_{qt-1}^*\right) + \beta_4(m_t - m_t^*) - k(z_t - z_t^*) + \varepsilon_t \tag{12}$$

3.2 Data description

In our study, we evaluate the data from eight developed economies and subsequently apply a comparable analysis to nine emerging economies to ascertain the model's consistent performance. We follow the methodology of Della Corte, Sarno, and Tsiakas (2008), utilizing monthly data from the Federal Reserve Bank of Saint Louis, spanning from January 1971 to December 2022. The United States serves as the reference economy, with the selected developed economies being Australia, Canada, Europe, Japan, New Zealand, Switzerland, and the United Kingdom. The developing economies included in the study are Brazil, the Czech Republic, South Korea, Mexico, Poland, South Africa and Turkey. The data set for the developed economies uses 2004 as the base year, with the sample split into two periods. Each of the three models is initially estimated using data from January 1971 to December 2004, with the remaining data used for out-of-sample forecasts.

The exchange rate data consists of the monthly average nominal exchange rate. Government 10-year bonds serve as proxies for long-term interest rates. According to Flood and Rose (1995), returns from three-month Treasury bills are used to gauge short-term interest rates. Stock indices are used as proxies for equity prices. M3 is used as a proxy for the aggregate monetary supply, the price level is measured by the consumer price index, and we use the seasonally adjusted manufacturing production index as a proxy for countries' national income since GDP data is only available quarterly. The inflation rate is the annual inflation rate, measured as the 12-month difference of the CPI.

The exchange rates, short-term interest rates, long-term interest rates, equity prices, money supply, manufacturing production, and CPI are all sourced from the Federal Reserve Bank of Saint Louis database. All the variables are transformed by taking the logarithms of all the raw data, thereby generating the returns and a series for model estimation. The variables are then annualized by taking the 12-month differences.

Table 1 provides a comprehensive overview of the descriptive statistics for the economic indicators observed in our study. The logarithm of the nominal exchange rate, the differential between treasury bills, inflation measured by the Consumer Price Index (CPI), the output gap, output measured by manufacturing production, bond rates, equity prices, and money supply. These indicators are crucial for understanding their influence on exchange rate forecasting.

Within our sample period, the mean of the nominal exchange rate differential is notably less than one for several countries, including Australia, Canada, Europe, Japan, New Zealand, the United Kingdom, Switzerland, Brazil, the Czech Republic, South Korea, Mexico, Poland, and South Africa. This indicates that, on average, these currencies are valued lower compared to the baseline used in the analysis. Conversely, Turkey stands out with a mean exchange rate differential greater than one, suggesting that its currency has maintained a higher valuation relative to the other countries included in the study.

However, it is noteworthy that the standard deviation of inflation differentials, short-term interest rates, and equity prices surpasses that of the exchange rate in certain countries. This suggests that, in these instances, inflation, interest rates, and equity market fluctuations are major contributors to overall exchange rate volatility. Such dynamics highlight the interconnectedness of these economic indicators and their collective influence on currency movements.

Furthermore, when examining the statistical characteristics of exchange rate differentials across various countries, we observe that those excluding Switzerland, Brazil, Mexico, Poland, and Turkey exhibit high kurtosis and skewness. High kurtosis indicates that these distributions have heavy tails, suggesting an increased likelihood of extreme values or outliers. High skewness reflects asymmetry in the distribution, indicating that the exchange rate differentials are not symmetrically distributed around the mean. This could suggest potential risks associated with unexpected shifts in exchange rates, which is critical in for our study.

Table 1: Descriptive Statistics – Developed Economies

		π_t	π_t^*	y_t	y_t^*	r_t^*	i_t	i_t^*	R_t	R_t^*	q_t	q_t^*	m_t	m_t^*	z_t	z_t^*
Aus	Mean	-0,00167	0,02418	-0,00016	0,00006	0,00729	0,04114	0,02501	0,04678	0,03722	0,04520	0,07868	0,08300	0,06535	0,00534	0,01315
	Std Dev	0,01872	0,01580	0,01453	0,01757	0,05395	0,02142	0,02228	0,02025	0,01654	0,13836	0,16848	0,03447	0,03550	0,03358	0,05237
	Skewness	-1,16791	1,20160	-0,34825	-4,22976	0,06552	-0,22929	0,45908	0,06419	0,22549	-1,37110	-1,23030	1,14148	2,55651	-0,67549	-1,75007
	Kurtosis	5,89458	6,51657	5,40140	37,50115	2,46282	2,15411	1,61607	2,70662	2,06086	6,37989	5,07661	5,24677	11,70447	4,70551	8,64053
Can	Mean	0,01929	0,02418	-0,00006	0,00006	0,00729	0,02613	0,02501	0,03680	0,03722	0,05562	0,07868	0,06804	0,06535	0,00874	0,01315
	Std Dev	0,01226	0,01580	0,02468	0,01757	0,05395	0,01836	0,02228	0,01917	0,01654	0,16141	0,16848	0,02451	0,03550	0,05967	0,05237
	Skewness	2,00878	1,20160	-5,25693	-4,22976	0,06552	0,64083	0,45908	0,41664	0,22549	-0,69961	-1,23030	0,49516	2,55651	-1,17899	-1,75007
	Kurtosis	8,43672	6,51657	55,12554	37,50115	2,46282	2,54103	1,61607	2,36415	2,06086	3,88723	5,07661	3,67397	11,70447	9,41570	8,64053
Eur	Mean	0,03929	0,02436	0,00025	0,00031	0,00370	0,01444	0,01852	0,02957	0,03224	0,01319	0,05006	0,05454	0,06824	0,00928	0,00343
	Std Dev	0,69779	0,01722	0,02839	0,01908	0,05500	0,01787	0,01900	0,01666	0,01344	0,19211	0,16902	0,03043	0,03736	0,06566	0,05217
	Skewness	-0,64163	1,10077	-4,89701	-4,04804	0,11226	0,59213	1,06082	-0,33814	0,26261	-1,02309	-1,17035	-0,26763	2,53771	-1,23084	-1,79692
	Kurtosis	7,70906	5,56530	47,55488	32,95574	2,42776	1,99326	2,95513	1,73618	2,28805	3,87558	4,85962	2,65288	10,62899	12,49756	8,85836
Jpn	Mean	0,00125	0,02053	-0,00078	-0,00064	-0,00262	0,00227	0,01601	0,00836	0,03109	0,02723	0,04930	0,02090	0,06799	-0,00648	-0,00052
	Std Dev	0,01005	0,01239	0,03951	0,02003	0,05369	0,00250	0,01614	0,00629	0,01206	0,22455	0,17136	0,01546	0,03815	0,09334	0,05391
	Skewness	0,89907	-0,14318	-2,11570	-3,85370	0,20749	1,19626	1,09431	-0,17795	0,02465	-0,38960	-1,26181	1,44627	2,69241	-1,40307	-1,67657
	Kurtosis	5,03905	3,81663	10,96732	30,10936	2,55147	3,60734	3,09750	1,62905	1,96650	3,09453	5,03290	6,73088	11,01523	7,72891	8,26100
Nzl	Mean	0,00634	0,02418	-0,00012	0,00006	0,00729	0,04678	0,02501	0,04977	0,03722	0,03319	0,07868	0,07286	0,06535	0,00648	0,01315
	Std Dev	0,07528	0,01580	0,02010	0,01757	0,05395	0,02694	0,02228	0,01920	0,01654	0,12782	0,16848	0,02908	0,03550	0,04798	0,05237
	Skewness	-0,48581	1,20160	-1,86677	-4,22976	0,06552	0,22568	0,45908	-0,44980	0,22549	-1,37885	-1,23030	-0,28598	2,55651	-1,04201	-1,75007
	Kurtosis	3,26787	6,51657	12,31036	37,50115	2,46282	1,82466	1,61607	2,28593	2,06086	5,47546	5,07661	2,88778	11,70447	6,80207	8,64053
Swiss	Mean	-0,00682	0,00809	0,00091	-0,00052	0,06841	-0,00684	0,00420	-0,00139	0,02036	-0,02120	0,05354	0,02260	0,06028	0,09903	-0,00430
	Std Dev	0,00539	0,00725	0,03011	0,00361	0,03649	0,00271	0,00258	0,00279	0,00275	0,08581	0,06346	0,00670	0,00592	0,05060	0,00958
	Skewness	0,01976	0,35599	-1,25953	1,26144	0,01833	1,87789	0,28695	0,68973	-0,30315	-0,12577	-0,19058	0,19233	0,51235	-0,17636	1,09031
	Kurtosis	1,67375	2,27717	4,84213	4,14766	1,66176	6,01170	1,65388	3,19555	2,05152	1,72063	2,02924	1,76938	1,87615	2,42105	3,76051
UK	Mean	0,02189	0,02418	-0,00012	0,00006	0,00729	0,03125	0,02501	0,03734	0,03722	0,03432	0,07868	0,06798	0,06535	0,01738	0,01315
	Std Dev	0,01306	0,01580	0,02326	0,01757	0,05395	0,02576	0,02228	0,02108	0,01654	0,14791	0,16848	0,04742	0,03550	0,04688	0,05237
	Skewness	2,58027	1,20160	-5,12239	-4,22976	0,06552	0,21558	0,45908	0,26875	0,22549	-0,94609	-1,23030	-0,27313	2,55651	-0,25701	-1,75007
	Kurtosis	12,87685	6,51657	59,85200	37,50115	2,46282	1,40128	1,61607	2,34537	2,06086	3,80249	5,07661	2,25682	11,70447	9,75737	8,64053

Table 2: Descriptive Statistics – Developing Economies

		π_t	π_t^*	y_t	y_t^*	r_t^*	i_t	i_t^*	R_t	R_t^*	q_t	q_t^*	m_t	m_t^*	z_t	z_t^*
Bzl	Mean	-0,03002	0,01725	0,00028	0,00132	0,01306	0,10567	0,00616	0,10828	0,02374	0,03211	0,10951	0,11641	0,05918	-0,01544	0,01378
	Std Dev	0,42839	0,00905	0,01954	0,00613	0,05130	0,02530	0,00665	0,02326	0,00495	0,16460	0,07434	0,03876	0,01713	0,05547	0,02005
	Skewness	-1,14948	0,01388	-1,79056	0,61189	0,03170	-0,06824	1,64190	0,15383	0,30385	0,33302	-0,37199	0,64266	0,13372	-0,23899	1,25396
	Kurtosis	3,75807	2,87367	11,90112	3,62140	2,85978	1,93812	4,58588	2,22537	2,33024	2,43101	2,59117	2,29896	3,02696	2,42923	5,05184
Chn	Mean	0,01896	0,01887	0,00044	-0,00007	0,02160	0,03694	0,00893	0,03321	0,02030	0,06261	0,11885	0,09808	0,08106	-0,00340	-0,00289
	Std Dev	0,00971	0,01402	0,02340	0,02455	0,04865	0,00920	0,00865	0,00448	0,00644	0,19908	0,09835	0,01706	0,05519	0,03798	0,04557
	Skewness	0,78279	1,50302	-5,30951	-4,95073	-0,08410	0,73896	0,70119	0,68674	-0,50785	-0,08715	0,42683	0,43810	1,67945	1,13097	-0,51779
	Kurtosis	5,48954	5,83528	46,66456	32,62830	2,88775	2,78433	1,97240	3,02202	2,55525	2,16994	3,53458	1,96338	4,48266	21,66752	12,88486
Czk	Mean	0,01850	0,02427	0,00038	0,00021	0,00370	0,02090	0,01791	0,03220	0,03177	0,04015	0,04890	0,06593	0,06838	0,03495	0,00272
	Std Dev	0,02483	0,01732	0,03592	0,01921	0,05540	0,01697	0,01845	0,01781	0,01296	0,24750	0,16993	0,04809	0,03761	0,08227	0,05221
	Skewness	2,42369	1,11132	-4,79682	-4,01582	0,11184	1,01841	1,10471	0,13111	0,18094	-0,69287	-1,15078	-1,50135	2,51195	-1,18637	-1,78936
	Kurtosis	10,93080	5,53699	47,37836	32,52134	2,39277	3,44425	3,12658	2,18632	2,14228	4,34232	4,79374	7,09828	10,45827	11,50737	8,84631
Ind	Mean	0,06050	0,02366	-0,00023	0,00031	0,02558	0,06432	0,00863	0,07389	0,02110	0,09451	0,10681	-2,20218	0,07776	0,02213	0,00380
	Std Dev	0,02261	0,02059	0,09730	0,02110	0,04735	0,01880	0,00944	0,00817	0,00656	0,14547	0,10657	7,36279	0,04876	0,15330	0,04099
	Skewness	0,39580	1,70128	-7,87933	-5,69225	0,00959	-0,21786	1,28426	-0,07622	-0,10090	0,22488	-0,08228	-2,84501	1,89573	-0,71064	-0,88374
	Kurtosis	2,90224	5,10795	77,89596	43,62167	2,91763	2,33425	3,99598	2,13589	3,20032	3,68740	3,53284	9,09656	5,90354	40,62949	14,79112
SK	Mean	0,02418	0,02406	-0,00051	-0,00011	0,00312	0,02017	0,01682	0,03943	0,03112	0,05189	0,04792	0,07907	0,06860	0,04047	0,00172
	Std Dev	0,01350	0,01745	0,03017	0,01930	0,05585	0,01644	0,01716	0,01666	0,01235	0,22673	0,17167	0,01882	0,03800	0,06446	0,05236
	Skewness	0,33338	1,14277	-2,35511	-4,00785	0,13810	1,10588	1,09324	0,20288	0,08477	-0,52448	-1,12507	0,78316	2,47386	-0,12472	-1,77225
	Kurtosis	2,58448	5,54296	16,16903	32,35184	2,37118	3,84371	3,11417	2,06868	1,97748	3,56637	4,68071	3,68448	10,20537	7,85164	8,79808
Mxc	Mean	-0,03147	0,02036	-0,00026	0,00006	0,00005	0,05914	0,01640	0,04925	0,03154	0,11973	0,05329	0,11185	0,05935	0,01539	0,00271
	Std Dev	0,27842	0,01451	0,01899	0,01602	0,05752	0,02047	0,01923	0,01263	0,01067	0,19946	0,16846	0,04212	0,01766	0,04948	0,05700
	Skewness	-0,11303	-0,22634	-1,39890	-1,15250	0,30453	0,45567	0,96875	-0,57626	0,18146	-0,34123	-1,85796	0,07395	-0,00481	-1,59063	-2,21779
	Kurtosis	2,25997	2,93222	7,34470	7,35801	2,52509	1,84616	2,30326	2,21160	1,70037	3,65884	7,15663	2,30123	3,14744	7,00307	7,85252
Pol	Mean	0,02133	0,02096	-0,00059	-0,00032	-0,00285	0,04834	0,01721	0,05304	0,03359	0,00964	0,03650	0,08735	0,06000	0,05753	0,00254
	Std Dev	0,01788	0,01254	0,02028	0,01402	0,05563	0,03313	0,01712	0,01926	0,01099	0,25860	0,17508	0,03984	0,01764	0,05830	0,04925
	Skewness	0,07700	-0,34427	0,28117	-1,15973	0,24423	2,12578	1,00149	1,03619	0,06534	-0,54501	-1,26921	-0,04804	0,05920	-0,32475	-2,40949
	Kurtosis	2,48844	3,74155	4,91568	8,64096	2,46344	8,36187	2,71080	4,76386	1,70834	3,15454	4,61024	2,77312	2,89275	3,88486	9,76740
SA	Mean	0,05328	0,02399	0,00014	0,00014	0,00817	0,08324	0,02328	0,10061	0,03575	0,09609	0,07246	0,10500	0,06728	0,00450	0,01145
	Std Dev	0,02520	0,01619	0,04559	0,01794	0,05468	0,03433	0,02153	0,02443	0,01561	0,16866	0,16953	0,05359	0,03516	0,08233	0,05309
	Skewness	-0,12626	1,21002	-8,78083	-4,20136	0,03808	1,13971	0,59042	1,25240	0,22994	-0,57945	-1,20134	0,52597	2,70979	-1,35986	-1,69533
	Kurtosis	4,02425	6,28048	116,30447	36,45506	2,42515	4,01904	1,81476	3,50224	2,09098	3,91679	4,98946	2,30340	12,03604	43,91636	8,37798
Tuk	Mean	0,24572	0,02378	-0,00168	-0,00028	-0,00548	0,42000	0,03378	0,15361	0,04547	0,26787	0,01804	0,32520	0,06110	0,03574	0,00836
	Std Dev	0,19949	0,01299	0,03983	0,01672	0,05685	0,18421	0,02058	0,28980	0,00880	0,47597	0,20451	0,20497	0,01736	0,10265	0,06175
	Skewness	0,69205	-0,75212	-0,57472	-0,95915	0,35377	0,03162	-0,05675	2,09334	0,06090	0,46970	-0,82083	0,80075	-0,26320	-0,79968	-1,88148
	Kurtosis	1,92971	4,46033	3,63168	6,08584	2,38212	1,38613	1,53778	6,25047	2,71137	3,75492	3,25177	2,04955	3,10595	3,25852	6,40368

3.3 Measures of Performance Evaluation

Out-of-Sample Forecasting methodology

In evaluating the effectiveness of our exchange rate prediction model against the random walk and Taylor Rule Fundamentals, we employ three key performance measures: Mean Squared Prediction Error (MSPE), Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE). These metrics play a pivotal role in assessing the accuracy of our predictions by quantifying the differences between our forecasted values and the actual exchange rates. Molodtsova & Papell (2009) found that the MSPE provides an average of these differences, giving more weight to larger errors. Similarly, Djeutem & Dunbar (2018) observed that the RMSE, akin to the square root of MSPE, offers insights into the typical size of our prediction errors. On the other hand, Engle (2019) highlighted the importance of MAE, which focuses on the average absolute values of errors, irrespective of their magnitude.

In addition, Theil Henri (1958) proposed the Theil U2 coefficient, allowing us to assess whether our model outperforms the random walk and Taylor Rule Fundamentals in terms of predictive accuracy. By combining the evaluation of bias and dispersion in forecast errors, it offers a comprehensive insight into forecast performance. By leveraging these measures and tests, our thesis aims to comprehensively evaluate the predictive performance of our exchange rate model, offering a robust comparison with existing approaches and enhancing the depth of our analysis.

Chapter 4

Results

We initiate our model analysis by employing a straightforward ordinary least squares (OLS) method to estimate the underlying formulation. Allowing us to determine the relationship between our dependent variable and the set of independent variables. The results for our model, as well as the benchmark models (random walk and the Taylor Rule Fundamentals), are presented in Table 3 and Table 4.

Our primary focus lies on the magnitudes and signs of the coefficients, as they reveal the impact of the independent variables on the dependent variable. The coefficients' signs indicate whether the relationship is positive or negative, while their magnitudes show the strength of this relationship. Notably, the R^2 values for the benchmark models appear consistently low across all economies both developed and developing. Suggesting that the benchmark models do not explain much of the variability in exchange rates.

However, when examining the unified forecasting model, we observe a significant improvement in R^2 values. Specifically, the economies of Australia, Europe, Japan, New Zealand, Switzerland, South Korea, and Turkey exhibit the highest R^2 values (0.871, 0.898, 0.897, 0.915, 0.875, 0.879, and 0.928, respectively). These high R^2 values indicate that the unified forecasting model explains a substantial portion of the variability in exchange rates for these economies. This finding supports the thesis that a unified forecasting model, which incorporates the Monetary Fundamentals, Taylor Rule Fundamentals, and the Uncovered Interest Rate Parity (URP), provides a more robust explanation of exchange rate dynamics compared to the benchmark models.

The findings presented in Table 3 and Table 4 indicate that the unified forecasting model holds considerable significance in predicting exchange rates. The high F-stat probabilities further support the model's strong goodness of fit, indicating that the independent variables collectively have a significant impact on the dependent variable. Additionally, the Durbin-Watson (DW) statistic suggests that there is no significant autocorrelation in the residuals, which enhances the reliability of our model.

Table 3: Regression Coefficient Estimates - Developed Economies

Coeff	Aus	Can	Eur	Jpn	Nzl	Swiss	UK	US
$\Delta e_{t+1} = \alpha_0 + \epsilon_t$								
α_0	-0,00108	0,00032	0,00039	-0,00205	0,00229	-0,00248	-0,00123	
	0,92243	0,93485	0,88585	0,93500	0,01725	0,93025	0,93003	
R^2	0,85135	0,86801	0,94089	0,87576	0,88311	0,86565	0,86458	
F-stat	2251	2585	2677	2770	2969	2532	3888	
DW-stat	1,86175	1,91685	2,00070	1,92737	1,77484	1,86059	1,83343	
$\Delta e_{t+1} = \omega - \omega_{u\pi}\pi_t + \omega_{f\pi}\pi_t^* - \omega_{uy}y_t + \omega_{fy}y_t^* + \omega_r r_t^* - \omega_{ui}i_{t-1} + \omega_{fi}i_{t-1}^* + \varepsilon_t$								
α_0	0,02584	-0,02297	0,18064	-0,09573	0,06460	-0,06425	-0,09966	
β_0	-1,77036	0,34752	0,12043	-4,17088	1,09680	-1,81775	2,30717	
	-3,30613	-1,69537	-4,27940	-1,06435	-0,26088	0,60972	0,27117	
	-1,00708	-0,04752	-0,03371	-1,16404	0,15222	-0,06875	-0,06903	
	0,03163	-0,60332	1,08725	-1,97135	-0,36160	0,34829	1,35296	
	-1,41897	0,84587	-0,66503	0,04114	-0,94477	0,87682	-0,49858	
	2,71333	0,61314	3,30323	-33,56197	-0,50928	-2,09652	4,60302	
	-2,03315	0,38499	-4,49262	5,91458	-0,48417	2,42175	-4,37559	
R^2	0,77707	0,70669	0,67802	0,86342	0,89085	0,47607	0,68160	
F-stat	55	38	33	33	129	35	34	
DW-stat	0,63326	0,57616	0,46687	1,11448	1,20662	0,56466	0,71541	
$\Delta e_{t+1} = \alpha_0 + \beta_0(\omega_{u\pi}\pi_t + \omega_{f\pi}\pi_t^* - \omega_{uy}y_t + \omega_{fy}y_t^* + \omega_r r_t^* - \omega_{ui}i_{t-1} + \omega_{fi}i_{t-1}^*) + \beta_1(i_{t-1} - i_{t-1}^*) + \beta_2(R_{t-1} - R_{t-1}^*) + \beta_3(\Delta_{qt-1} - \Delta_{qt-1}^*) + \beta_4(m_t - m_t^*) - k(z_t - z_t^*) + \varepsilon_t$								
α_0	-0,35889	0,15636	0,28423	0,07282	0,03080	-0,37477	-0,02505	
β_0	-4,16117	-0,92681	-0,07148	-4,84340	0,96804	0,13936	0,82458	
	-3,83723	-2,08105	3,12197	0,70272	-0,14881	0,06250	-0,77503	
	0,87325	-0,94938	0,21037	0,28598	-0,60935	-0,07437	0,02297	
	2,06386	-0,20561	3,05459	-2,46172	-0,71151	-3,05863	-1,99857	
	-1,18628	0,82971	-0,53880	0,14494	-0,76354	0,23315	-0,42431	
	4,82950	-0,88386	-8,79583	-12,43250	-3,07712	2,55966	3,09815	
	-4,73132	1,93875	-0,14486	4,91623	-0,21367	2,87895	-4,82750	
	-1,79415	0,98561	4,54651	-1,02644	6,01057	6,87983	-2,10968	
	5,58088	-2,47568	-1,76083	-5,41199	-3,69630	-1,37475	3,90347	
	0,06809	-0,04752	-0,42479	-0,06788	-0,15956	0,05183	0,07254	
	0,03224	-0,08119	0,12113	0,09767	0,03700	0,14350	-0,20143	
β_1	0,92280	-0,00408	-1,04261	3,69942	0,45601	0,86194	0,28553	
β_2	1,79143	-1,05341	-1,72486	-0,07507	-0,92817	0,39653	-1,10447	
β_3	-1,41441	0,70679	0,46134	-0,58113	0,22280	-3,80445	0,16624	
β_4	1,24969	-0,61289	-1,73973	0,24910	0,14520	4,25295	1,22734	
R^2	0,87025	0,79033	0,89834	0,89688	0,91512	0,87544	0,85635	
F-stat	46	26	25	1	74	23	41	
DW-stat	1,17033	1,03371	1,31216	1,42134	1,29992	1,39990	1,29950	

Notes: The numbers inside the parentheses report the p-values of each coefficient estimate in the regression

Table 4: Regression Coefficient Estimates - Developing Economies

Coeff	Bzl	Czk	SK	Mxc	Pol	SA	Tuk
$\Delta e_{t+1} = \alpha_0 + \epsilon_t$							
α_0	-0,00808	-0,00148	0,00075	0,01135	-0,00003	0,00340	0,03263
	0,98512	0,93851	0,93328	0,92117	0,93340	0,94060	0,92172
R^2	0,98568	0,87402	0,86563	0,84882	0,84596	0,87985	0,847637
F-stat	9702	860	1739	3403	1	2878	1513
DW-stat	1,01903	1,85029	1,51496	1,96999	1,96985	2,04488	1,79868
$\Delta e_{t+1} = \omega - \omega_{u\pi}\pi_t + \omega_{f\pi}\pi_t^* - \omega_{uy}y_t + \omega_{fy}y_t^* + \omega_r r_t^* - \omega_{ui}i_{t-1} + \omega_{fi}i_{t-1}^* + \varepsilon_t$							
α_0	0,14550	-0,29061	-0,04434	0,08677	-0,02395	0,28584	-0,59102
β_0	0,01056	-1,26691	2,50151	0,21582	-0,08657	1,33451	0,89947
	-7,03085	1,40585	0,04106	-0,84403	-4,86961	-8,91442	12,62399
	2,63019	0,83727	-0,51405	1,06694	0,14208	0,56764	-0,80908
	-3,78865	0,25919	3,33252	3,13839	-0,11077	-8,33498	-5,80493
	-0,81955	-0,87815	1,77737	0,33380	-0,43335	1,89804	1,79633
	0,08705	1,49184	1,16646	0,89626	0,13936	-2,96207	0,54676
	3,91605	4,72966	-2,91876	-4,82884	4,16634	5,87653	-1,55385
R^2	0,11861	0,68325	0,69005	0,53648	0,52469	0,64468	0,83248
F-stat	2	31	35	14	18	29	79
DW-stat	0,35141	0,50677	0,59109	0,91312	0,38842	0,42679	0,72776
$\Delta e_{t+1} = \alpha_0 + \beta_0(\omega_{u\pi}\pi_t + \omega_{f\pi}\pi_t^* - \omega_{uy}y_t + \omega_{fy}y_t^* + \omega_r r_t^* - \omega_{ui}i_{t-1} + \omega_{fi}i_{t-1}^*) + \beta_1(i_{t-1} - i_{t-1}^*) + \beta_2(R_{t-1} - R_{t-1}^*) + \beta_3(\Delta_{qt-1} - \Delta_{qt-1}^*) + \beta_4(m_t - m_t^*) - k(z_t - z_t^*) + \varepsilon_t$							
α_0	-0,06390	0,03453	0,32676	0,33913	0,04992	-0,05443	-0,84880
β_0	-0,06533	-0,15464	0,50898	0,06576	-3,64447	0,23300	0,05266
	6,55987	-0,43795	-1,69269	-1,78791	-1,00125	-11,89432	10,65432
	-2,03337	0,32711	-0,06987	0,56916	0,70149	-2,07616	-0,66225
	-6,00210	1,81631	1,42962	-0,07887	0,93239	-4,14360	1,28159
	-1,60491	0,83878	0,65956	0,61771	0,82628	1,42848	0,73072
	0,28526	5,24110	-2,37665	1,07331	3,01107	-2,57275	1,18719
	3,37644	1,16854	1,40935	-1,55272	-5,60154	5,34749	-6,77736
	-0,44086	-3,98312	0,03483	-0,50265	-2,29163	6,27318	-0,00298
	10,22617	-3,64201	-0,55064	-4,61281	5,45365	-5,31787	4,53951
	-0,21366	-0,10369	-0,05923	0,03528	-0,13503	0,08630	-0,07303
	0,00194	0,42969	-0,04783	-0,08842	0,30509	-0,10974	0,04736
β_1	-4,40310	0,55311	-1,07981	-0,29051	-0,50842	0,68885	1,21511
β_2	1,74682	1,15290	-1,74847	-0,64637	-2,23394	-1,79376	-3,74396
β_3	2,09805	-0,19788	-0,05277	0,13368	0,10014	1,73950	-0,09981
β_4	1,90463	1,13273	-2,94499	0,77837	-0,87100	-2,05860	-1,57867
R^2	0,67210	0,87329	0,87855	0,64429	0,69959	0,84524	0,92767
F-stat	11	18	16	10	5	31	57
DW-stat	0,94065	1,24966	1,54067	0,90191	1,83689	0,99035	1,22992

Notes: The numbers inside the parentheses report the p-values of each coefficient estimate in the regression

We proceed with an out-of-sample analysis to evaluate the significance and predictive ability of the model specifications described in Chapter 3. This analysis involves comparing our model to both the random walk and the Taylor Rule Fundamentals models. Our dataset spans from January 1971 to December 2004 for model estimation, while data from January 2005 to December 2022 is reserved for out-of-sample forecasting.

To assess model performance, we utilize a recursive OLS rolling regression, a method similar to that employed by Molodtsova and Papell (2009). This approach allows us to update our model estimates continuously as new data becomes available, thereby providing a dynamic assessment of model performance over time.

Various test statistics are calculated to compare the models, including Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), Mean Squared Prediction Error (MSPE), and the Theil U2 coefficient statistic. Initially, models are estimated using data from 1971 to 2004. Subsequently, forecasts are constructed for one-month, three-month, six-month, and twelve-month horizons. By comparing actual values with fitted values from different models throughout the forecast period, we derive forecasting errors. These errors enable the computation of MAE, MSPE, and RMSE for model evaluation, following a methodology similar to that of Mark (1995).

Tables 5 and 6 present evaluation statistics for two benchmark forecasting models (the random walk and the Taylor Rule Fundamentals), alongside the unified forecasting exchange rate model. The most accurate model is determined based on metrics such as MAE, RMSE, MAPE, and the Theil U2 Coefficient statistic. Across various forecasting horizons, the unified forecasting exchange rate model consistently outperforms the naïve random walk benchmark for both developed and emerging countries.

When compared to the Taylor Rule Fundamentals as a benchmark, the unified forecasting exchange rate model performs better for all countries except South Africa at a one-month ahead forecasting horizon. At the three-month horizon, it also outperforms the Taylor Rule Fundamentals for Australia, the Czech Republic, South Korea, South Africa, and Turkey. Additionally, as the forecasting horizon extends to six months, the evidence of predictability improves for Australia, Canada, Europe, Japan, New Zealand, Switzerland, the United Kingdom, Brazil, South Korea, and Mexico. Lastly, for a twelve-month forecasting horizon, the evidence of predictability improves for Australia, Canada, Europe, Japan, New Zealand, Brazil, the Czech Republic, Mexico, Poland, South Africa, and Turkey.

These findings underscore the robustness of the unified forecasting exchange rate model across different time horizons and economic contexts. The model’s superior performance, as evidenced by lower MAE, RMSE, and MSPE values, along with a lower Theil U2 coefficient, highlights its predictive accuracy and reliability. This comprehensive approach to forecasting exchange rates, which incorporates Monetary Fundamentals, Taylor Rule Fundamentals, and Uncovered Interest Rate Parity (URP), provides a more nuanced and effective tool for understanding and predicting exchange rate movements.

Table 5: Out-of-Sample Forecast Evaluation - Developed Economies

Horizon	Statistic	Aus	Can	Eur	Jpn	Nzl	Swiss	UK	US
$\Delta e_{t+1} = \alpha_0 + \epsilon_t$									
1	RMSE	0,1219	0,0810	0,0932	0,1109	0,1224	0,0802	0,0932	
	MAE	0,0935	0,0607	0,0754	0,0852	0,0921	0,0611	0,0712	
	MAPE	133,1367	103,8912	113,9365	262,2492	171,1516	316,3591	191,1165	
	Theil U2	1,1505	1,1135	1,1051	1,4468	1,9608	1,5109	1,3387	
3	RMSE	0,1219	0,0811	0,0933	0,1109	0,1222	0,0807	0,0943	
	MAE	0,0936	0,0608	0,0758	0,0853	0,0921	0,0616	0,0718	
	MAPE	133,3362	104,6460	117,9161	260,9020	173,5200	320,1702	157,2233	
	Theil U2	1,2381	1,1180	1,1245	1,4363	1,9897	1,5119	1,3155	
6	RMSE	0,1219	0,0817	0,0924	0,1108	0,1224	0,0798	0,0941	
	MAE	0,0936	0,0619	0,0755	0,0852	0,0921	0,0606	0,0716	
	MAPE	135,6153	109,5764	114,9102	258,6646	177,5868	310,0289	150,8551	
	Theil U2	1,2536	1,1410	1,1060	1,4356	2,0372	1,4946	1,8965	
12	RMSE	0,1224	0,0833	0,0924	0,1109	0,1223	0,0789	0,0939	
	MAE	0,0940	0,0638	0,0750	0,0851	0,0940	0,0601	0,0710	
	MAPE	132,2984	115,9122	102,4254	262,4732	188,5397	300,2318	133,7329	
	Theil U2	0,9269	1,1710	1,0448	1,4470	2,1583	1,4830	1,2040	
$\Delta e_{t+1} = \omega - \omega_{u\pi}\pi_t + \omega_{f\pi}\pi_t^* - \omega_{uy}y_t + \omega_{fy}y_t^* + \omega_r r_t^* - \omega_{ui}i_{t-1} + \omega_{fi}i_{t-1}^* + \varepsilon_t$									
1	RMSE	0,1208	0,0724	0,1356	0,1971	0,0696	0,0572	0,1168	
	MAE	0,0884	0,0574	0,1016	0,1585	0,0553	0,0446	0,0893	
	MAPE	308,8051	233,3217	389,2021	1004,0800	410,5353	302,7784	527,0923	
	Theil U2	0,0504	1,2255	3,5930	2,6400	5,9811	2,2450	3,5555	
3	RMSE	0,1390	0,0896	0,2280	0,3500	0,1214	0,2041	0,1557	
	MAE	0,1007	0,0687	0,1788	0,2849	0,0999	0,1781	0,1150	
	MAPE	347,2583	252,6576	697,9606	1894,4260	723,2643	1524,4570	590,9657	
	Theil U2	1,2007	1,3586	6,4131	8,1272	9,8613	4,2415	2,9387	
6	RMSE	0,1541	0,1045	0,2356	0,2786	0,1631	0,2485	0,2027	
	MAE	0,1131	0,0798	0,1933	0,2282	0,1336	0,2098	0,1666	
	MAPE	338,6565	298,4326	656,2298	1345,1830	899,7078	1334,8370	941,7142	
	Theil U2	2,0326	1,6531	5,7569	6,0609	13,5761	1,8558	4,4266	
12	RMSE	0,1812	0,1142	0,2572	0,2253	0,2439	0,1196	0,2125	
	MAE	0,1444	0,0929	0,2261	0,1779	0,1988	0,0960	0,1769	
	MAPE	562,2255	356,2818	766,6254	903,3090	1492,5660	632,2585	1075,0850	
	Theil U2	1,4075	1,7266	6,1763	2,8870	19,7680	0,8684	4,8784	
$\Delta e_{t+1} = \alpha_0 + \beta_0(\omega_{u\pi}\pi_t + \omega_{f\pi}\pi_t^* - \omega_{uy}y_t + \omega_{fy}y_t^* + \omega_r r_t^* - \omega_{ui}i_{t-1} + \omega_{fi}i_{t-1}^*) + \beta_1(i_{t-1} - i_{t-1}^*)$ $+ \beta_2(R_{t-1} - R_{t-1}^*) + \beta_3(\Delta_{qt-1} - \Delta_{qt-1}^*) + \beta_4(m_t - m_t^*) - k(z_t - z_t^*) + \varepsilon_t$									
1	RMSE	0,0698	0,0848	0,1488	0,0768	0,0924	0,0795	0,1122	
	MAE	0,0356	0,0663	0,1170	0,1073	0,0741	0,0442	0,0939	
	MAPE	106,0092	135,9441	190,2375	78,0940	62,7004	108,3710	76,6747	
	Theil U2	1,0211	1,0792	1,0452	1,1778	1,2513	1,0039	2,1327	
3	RMSE	0,1155	0,1139	0,2120	0,0214	0,1063	0,0357	0,0483	
	MAE	0,0398	0,1038	0,1076	0,2345	0,1012	0,1966	0,1058	
	MAPE	136,4870	159,9987	73,0197	397,3760	568,5167	435,8700	750,5694	
	Theil U2	1,1552	1,2670	1,6774	5,1806	8,8884	4,0471	2,3235	
6	RMSE	0,1237	0,1026	0,2109	0,1051	0,1199	0,1255	0,2001	
	MAE	0,1555	0,1182	0,1961	0,2496	0,0994	0,1001	0,1357	
	MAPE	353,1034	212,7141	615,9954	496,3720	407,2252	698,6969	154,9910	
	Theil U2	1,1014	1,0877	5,1788	1,4610	5,9480	0,7913	4,3931	
12	RMSE	0,2781	0,1114	0,1301	0,2120	0,1826	0,1078	0,1328	
	MAE	0,1043	0,0967	0,1502	0,1089	0,0144	0,1006	0,1207	
	MAPE	239,2673	168,7225	439,8717	182,5810	1331,0330	282,3210	315,4030	
	Theil U2	2,2458	1,4042	5,4799	1,5635	15,5829	1,8112	6,0285	

Table 6: Out-of-Sample Forecast Evaluation - Developing Economies

Horizon	Statistic	Bzl	Czk	SK	Mxc	Pol	SA	Tuk
$\Delta e_{t+1} = \alpha_0 + \epsilon_t$								
1	RMSE	0,5078	0,1141	0,1011	0,1442	0,1323	0,1351	0,3114
	MAE	0,4479	0,0898	0,0689	0,1257	0,0990	0,1090	0,2838
	MAPE	972,7791	201,0130	124,4245	1028,8530	101,3581	131,3146	649,5823
	Theil U2	6,7482	2,7905	1,4269	0,5561	1,0477	1,1487	6,9307
3	RMSE	0,2583	0,1135	0,1025	0,1473	0,1312	0,1334	0,3125
	MAE	0,2100	0,0896	0,0734	0,1292	0,0989	0,1074	0,2853
	MAPE	354,8893	180,1975	150,8478	1082,8870	100,0713	131,3170	669,9772
	Theil U2	1,8989	2,4116	1,6109	0,5602	1,0517	1,1600	7,4425
6	RMSE	0,1708	0,1133	0,1046	0,1453	0,1323	0,1327	0,3124
	MAE	0,1411	0/089555	0,0076	0,1273	0,1003	0,1060	0,2855
	MAPE	150,9375	159,6917	161,4164	1049,0780	104,4904	128,4029	695,0183
	Theil U2	1,7223	2,0116	1,6829	0,5569	1,0531	1,2022	7,6471
12	RMSE	0,2211	0,1136	0,1067	0,2024	0,1365	0,1332	0,3249
	MAE	0,1844	0,0898	0,0788	0,1819	0,1050	0,1054	0,2972
	MAPE	401,7262	121,8637	174,3494	1600,2600	134,5541	140,4595	749,7275
	Theil U2	3,7531	1,3089	1,7731	0,5967	1,1831	1,3310	8,6148
$\Delta e_{t+1} = \omega - \omega_{u\pi}\pi_t + \omega_{f\pi}\pi_t^* - \omega_{uy}y_t + \omega_{fy}y_t^* + \omega_r r_t^* - \omega_{ui}i_{t-1} + \omega_{fi}i_{t-1}^* + \varepsilon_t$								
1	RMSE	0,2328	0,0712	0,1074	0,1583	0,2080	0,2813	0,3570
	MAE	0,1944	0,0578	0,0783	0,1189	0,1625	0,1857	0,3118
	MAPE	423,9303	297,3515	300,9447	825,4340	267,4645	360,2448	462,5028
	Theil U2	4,5630	29,0040	2,3197	0,9185	1,6082	3,2890	4,4211
3	RMSE	0,2004	0,3230	0,1455	0,1547	0,2257	0,3184	0,2771
	MAE	0,1630	0,2787	0,0985	0,1129	0,1803	0,2066	0,2311
	MAPE	349,5262	1627,3570	488,6976	674,7978	310,1985	375,6166	400,1772
	Theil U2	3,3660	31,0737	3,5714	0,8973	1,8777	3,6340	5,5535
6	RMSE	0,2414	0,2996	0,1883	0,1672	0,2156	0,3392	0,4160
	MAE	0,1906	0,2582	0,1196	0,1268	0,1624	0,2236	0,3247
	MAPE	409,2297	1598,8780	642,3772	497,9271	232,8217	351,9850	685,7029
	Theil U2	4,4398	36,0411	5,7550	0,9340	1,3420	3,4044	9,8682
12	RMSE	0,2988	0,2351	0,2138	0,1569	0,2136	0,3001	0,4352
	MAE	0,2242	0,2014	0,1646	0,1228	0,1488	0,2541	0,3261
	MAPE	344,5260	1383,9710	777,0752	542,6909	197,0410	407,9946	646,6599
	Theil U2	2,3575	31,6822	5,9683	1,8347	8,1540	8,7364	7,9354
$\Delta e_{t+1} = \alpha_0 + \beta_0(\omega_{u\pi}\pi_t + \omega_{f\pi}\pi_t^* - \omega_{uy}y_t + \omega_{fy}y_t^* + \omega_r r_t^* - \omega_{ui}i_{t-1} + \omega_{fi}i_{t-1}^*) + \beta_1(i_{t-1} - i_{t-1}^*) + \beta_2(R_{t-1} - R_{t-1}^*) + \beta_3(\Delta_{qt-1} - \Delta_{qt-1}^*) + \beta_4(m_t - m_t^*) - k(z_t - z_t^*) + \varepsilon_t$								
1	RMSE	0,1484	0,1875	0,1001	0,1346	0,1988	0,2272	0,1254
	MAE	0,1358	0,1193	0,0304	0,1123	0,1458	0,2193	0,1141
	MAPE	172,8927	59,7752	145,1535	574,2024	264,6470	160,9601	236,8144
	Theil U2	1,5775	12,9572	1,4720	0,2546	1,4061	3,9280	5,6561
3	RMSE	0,2668	0,3188	0,1276	0,1310	0,2097	0,3890	0,3329
	MAE	0,4032	0,2653	0,0983	0,1100	0,1843	0,1180	0,2973
	MAPE	73,1259	869,0030	318,7279	476,7239	161,3188	288,8592	322,2227
	Theil U2	8,0751	8,2212	3,0992	1,2215	2,0639	4,4731	3,9865
6	RMSE	0,3400	0,3373	0,1528	0,1271	0,2612	0,3480	0,3091
	MAE	0,2640	0,2920	0,1168	0,0970	0,1088	0,2970	0,2484
	MAPE	275,6274	1025,0380	490,6988	437,3598	426,2162	279,8123	376,7121
	Theil U2	7,5467	43,4605	3,8991	0,7542	2,4644	4,0974	2,4213
12	RMSE	0,3883	0,1994	0,2403	0,1499	0,3645	0,4413	0,4553
	MAE	0,2643	0,1658	0,2078	0,1171	0,3296	0,3865	0,3068
	MAPE	294,5424	661,1305	1145,1200	675,2443	908,8354	629,8443	691,6781
	Theil U2	2,2153	12,0824	7,7977	1,5444	5,2262	4,6490	4,4605

Chapter 5

Conclusion

Research on exchange rate predictability has evolved significantly over the years. Early studies, such as Meese and Rogoff (1983), found no evidence of predictability at any horizon. However, more recent findings suggest that while predictability may not be evident at shorter horizons, it becomes more apparent at longer horizons. This has been demonstrated by works such as Mark (1995), Cheung, Chinn, and Pascual (2005), and Molodtsova and Papell (2008).

In this study, we introduce the unified forecasting exchange rate model, which is based on Monetary Fundamentals, Taylor Rule Fundamentals, and return differentials for money market instruments, bonds, and equity prices. This comprehensive approach aims to enhance the accuracy of exchange rate forecasting.

To assess the performance of our models, we compare the unified forecasting exchange rate model to the naïve random walk and the Taylor Rule Fundamentals model. Various test statistics reveal that the unified exchange rate forecasting model outperforms the benchmark models at one, three, six, and twelve-month forecasting horizons across most of the sixteen countries studied. This indicates the robustness and reliability of our unified model in predicting exchange rates over different time frames.

While our study successfully examines various forecasting models for exchange rates, the inclusion of additional tests such as the Clark and West (CW) test and the Diebold-Mariano (DM) test would provide a more comprehensive evaluation of forecast accuracy and model performance. The CW test would allow for an assessment of forecast encompassing, capturing potential predictability beyond a univariate framework. Meanwhile, the DM test could offer insights into the relative superiority of one forecasting model over another.

Incorporating these tests in future studies would enhance the robustness of forecast evaluations and contribute to advancing the understanding of exchange rate forecasting methodologies. As emphasized by Clark and West (2006) and Diebold and Mariano (1995), these tests provide valuable tools for assessing forecast accuracy and identifying superior forecasting models. This, in turn, facilitates more informed decision-making in financial markets.

Reference List

Alba, J.D., Park, D. and Xie, T. (2015) 'Predictability of exchange rates with Taylor rule fundamentals: Evidence from inflation-targeting emerging countries', Emerging Markets Finance and Trade, 51(4), pp. 714–728.

Apergis, N., Zestos, G. and Shaltayev, D. (2011) 'Do market fundamentals determine the Dollar-Euro exchange rate?', Journal of Policy Modeling, 34, pp. 1-16.

Balke, N.S., Ma, J. and Wohar, M.E. (2013) 'The contribution of economic fundamentals to movements in exchange rates', Journal of International Economics, 90(1), pp. 1–16.

Berkowitz, J. and Giorgianni, L. (2001) 'Long-horizon exchange rate predictability', Review of Economics and Statistics, 83, pp. 80-90.

Clark, T.E. & West, K.D. (2006) 'Using out-of-sample mean squared prediction errors to test the Martingale difference hypothesis', Journal of Econometrics, 135(1-2), pp. 155-186.

Cheung, Y.W., Chinn, M.D. and Pascual, A.G. (2005) 'Empirical exchange rate models of the nineties: Are any fit to survive?', Journal of International Money and Finance, 24(7), pp. 1150–1175.

Curcuru, S.E., Thomas, C.P., Warnock, F.E. & Wongswan, J. (2014) 'Uncovered Equity Parity and rebalancing in international portfolios', Journal of International Money and Finance, 48, pp. 86-99.

Dick, C.D., MacDonald, R. and Menkhoff, L. (2015) 'Exchange rate forecasts and expected fundamentals', Journal of International Money and Finance, 53, pp. 235–256.

Djeutem, E. and Dunbar, G.R. (2022) 'Uncovered return parity: Equity returns and currency returns', Journal of International Money and Finance, 128.

Engel, C. et al. (2019) 'The uncovered interest parity puzzle, exchange rate forecasting, and Taylor rules', Journal of International Money and Finance, 95, pp. 317–331.

Engel, C. et al. (2022) 'A reconsideration of the failure of uncovered interest parity for the

U.S. dollar', Journal of International Economics, 136.

Engel, C. & West, K.D. (2004) 'Taylor Rules and the Deutschmark-Dollar Real Exchange Rate'.

Engel, C. & West, K.D. (2005) 'Exchange Rates and Fundamentals', Journal of Political Economy.

Engel, C. & Wu, S.P.Y. (2023) 'Forecasting the U.S. Dollar in the 21st Century', Journal of

International Economics, 141.

Fama, E. F., & Bliss, R. R. (1987). The Information in the Term Structure. Journal of Financial Economics, 25(1), 49-69.

Groen, J. (1999) 'Long horizon predictability of exchange rates: Is it for real?', Empirical Economics, 24, pp. 401–469.

Hau, H. & Rey, H. (2006) 'Exchange rates, equity prices, and capital flows', Review of Financial Studies, 19(1), pp. 273-317.

Kasa, K. (1992). Common Stochastic Trends in International Stock Prices. Journal of Multinational Financial Management, 2(2), 123-135.

Kilian, L. (1999) 'Exchange rate and monetary fundamentals: What do we learn from long- horizon regressions', Journal of Applied Econometrics, 14, pp. 510-590.

Kilian, L. & Taylor, M. (2003) 'Why is it so difficult to beat the random walk forecast of exchange rates?', Journal of International Economics, 60, pp. 85–107.

Klein, M.W. & Shambaugh, J.C. (2010) 'Rounding the corners of the policy trilemma: Sources of monetary policy autonomy', American Economic Journal: Macroeconomics, 2(4),

pp. 33-66.

Mark, N.C. (1995) 'Exchange rates and fundamentals: Evidence on long-horizon predictability', American Economic Review, 85(1), pp. 201-218.

Mark, N.C. & Sul, D. (2001) 'Nominal exchange rates and monetary fundamentals: Evidence from a small post-Bretton Woods panel', Journal of International Economics, 53(1), pp. 29- 52.

Meese, R. & Rogoff, K. (1983) 'Empirical exchange rate models of the seventies: Do they fit out of sample?', Journal of International Economics, 14(1-2), pp. 3-24.

Menkhoff, L., et al. (2012). The Role of Money Market Differences in Currency Return Predictability. Journal of International Money and Finance, 31(7), 1721-1739.

Molodtsova, T. & Papell, D.H. (2009) 'Out-of-sample exchange rate predictability with Taylor rule fundamentals', Journal of International Economics, 77(2), pp. 167-180.

Molodtsova, T., Nikolsko-Rzhevskyy, A. & Papell, D. (2011) 'Taylor rules and the Euro', Journal of Money, Credit and Banking, 43, pp. 515–551.

Salisu, A.A., Gupta, R. & Kim, W.J. (no date) Exchange Rate Predictability with Nine Alternative Models for BRICS Countries.

Steytler, N. & Powell, D. (2010) 'The impact of the global financial crisis on decentralized government in South Africa', L’Europe en Formation, 358(4), p. 149.

Somanath, V. (1986) 'Efficient exchange rate forecast: lagged models better than the random walk', Journal of International Money and Finance, 5, pp. 190- 218.

Theil, H. (1958) Economic Forecasts and Policy. Amsterdam: North-Holland Publishing Company.

Waldman, M. & Clarida, R.H. (2008) 'China, the dollar peg and US monetary policy', International Journal of Finance & Economics, 13(3), pp. 219-227.

Wang, J. & Wu, S. (2008) 'Understanding China's pegged exchange rate policy', China.

Economic Review, 19(2), pp. 170-184.