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RESEARCH ARTICLE

Exchange Rates and Fundamentals in Developed and Emerging Markets

Rocky K. Laurel
University of the Philippines Diliman, Quezon City, Philippines
rocky.laurel@up.edu.ph

This paper investigates the relationship between exchange rates on the one hand and money supply and real output on the other, then compares the relationship in developed and emerging markets. It tests the validity of the flexible price monetary model using in-sample analysis to determine if there are long-term relationships among the variables and out-of-sample analysis to compare the predictive performance of the model against a random walk. It finds evidence for a relationship as predicted by the model, contrary to long-standing findings of no relationship. It also finds some evidence that foreign exchange rates of emerging markets are more predictable compared to those of developed markets.

Keywords: currencies, emerging markets, exchange rate predictability, flexible price, foreign exchange, international finance, monetary model, out-of-sample, random walk

JEL Classification: F31, F37

This study examines the relationship, or lack thereof, between exchange rates on the one hand and money supply and real output on the other, as predicted by the flexible price monetary model. It then compares the nature of the relationship in developed and emerging markets. Numerous studies have found no relationship among these variables, contrary to standard economic theory. This has become one of the major puzzles in international macroeconomics, known as the "exchange rate disconnect" (Obstfeld & Rogoff, 2000). The paper is partly motivated by the literature on the forward premium puzzle showing that exchange rates of developed markets behave differently from those of emerging markets when it comes to the uncovered interest parity relationship (Bansal & Dahlquist, 2000; Alper et al., 2009). Is there a similar disparity between developed and emerging foreign exchange markets when it comes to the relationship of exchange rates with fundamentals? The link between economic fundamentals and exchange rates will be evaluated using in-sample analysis involving cointegration tests, followed by an out-of-sample prediction analysis that has become standard in this line of research. It is also motivated by the lack of research on more recent foreign exchange rates, particularly in emerging markets. Most of the previous studies dealt with the Euro legacy currencies (e.g., German Deutschmark, French Franc, Italian Lira, etc.), which were homogeneous and highly correlated and may no longer be relevant because they have all been replaced by the Euro. Moreover, past studies suffered from a lack of data on emerging markets because most of their currencies were floated only in the 1990s.

This paper makes significant contributions to the literature on foreign exchange and emerging markets, addressing a gap in research that has predominantly focused on developed markets. Emerging markets possess distinct economic characteristics, including variations in output, income, interest rates, and inflation, which can influence exchange rate dynamics differently from developed economies. Although prior studies have explored foreign exchange rates in emerging markets, limitations such as insufficient long-term data have hindered comprehensive analysis. By employing a broader cross-section of emerging market countries, longer time-series data, and recent econometric methods, this paper offers a more robust understanding of how economic variables impact exchange rates in these regions.

The models to be tested are based on the flexible price monetary model, which relates the exchange rate to changes in the money supply and real output. This relationship may be understood intuitively as follows: Suppose there are two economies, one domestic and one foreign, each with its own currency. Assume purchasing power parity (PPP). An increase in the domestic money supply increases the domestic price level, which reduces the value of money relative to goods and leads to a depreciation of the domestic currency (or an appreciation of the foreign currency). On the other hand, an increase in domestic real output increases money demand, which increases the value of money relative to goods and reduces the price level, which in turn leads to an appreciation of the domestic currency (or a depreciation of the foreign currency), ceteris paribus. Therefore, the exchange rate, expressed as the domestic currency price of one foreign currency unit (FCU), is directly related to money supply and inversely related to real output.

More formally, the exchange rate is defined as the relative price of two monies. The demand for money m is assumed to depend on real output y, the price level p, and the level of the nominal interest i. Monetary equilibria (where money demand is equal to the money supply) in the domestic and foreign countries, respectively, can therefore be given by

$$m_t = p_t + \lambda y_t - \theta i_t \quad (1)$$

$$m_t^* = p_t^* + \lambda^* y_t^* - \theta^* i_t^* \quad (2)$$

with all variables expressed in logarithms except interest rates, and stars (*) are the quantities of the foreign country. Assume continuous purchasing power parity:

$$s_t = p_t - p_t^* \quad (3)$$

where s_t denotes the logarithm of the spot exchange rate at time t. Solving the three equations above for the exchange rate gives:

$$s_t = m_t - m_t^* - \lambda y_t + \lambda^* y_t^* + \theta i_t - \theta^* i_t^* \quad (4)$$

In practice, researchers often simplify the model by imposing $\lambda = \lambda^*$ and θ - θ^* (Taylor, 1995). Assuming uncovered interest parity, the expected change in exchange rate $(\Delta s_{t+1}^e = s_{t+1}^e - s_t)$ can substitute for the interest rate differential $(i_t - i^*_t)$ in the resulting equation to get:

$$s_t = (m_t - m_t^*) - \lambda(y_t - y_t^*) + \theta \Delta s_{t+1}^e \quad (5)$$

The rational expectations solution to this is

$$s_t = \frac{1}{1+\theta}\sum_{i=0}^{\infty}\left(\frac{\theta}{1+\theta}\right)^i E[(m-m^*)_{t+1} - \lambda(y-y^*)_{t+1} \mid \Omega_t] \quad (6)$$

where $E[\cdot \mid \Omega_t]$ denotes the mathematical expectation conditioned on the information set available at time t, Ω_t (Taylor, 1995).

This relationship is often examined using the following regression equation:

$$s_t = \alpha + \beta_1(m_t - m_t^*) + \beta_2(y_t - y_t^*) + u_t \quad (7)$$

where m_t = log money supply, y_t = log real output, u_t = error term (Cerra & Saxena, 2010); that is, the exchange rate is equal to the ratio of domestic money supply to foreign money supply plus the ratio of domestic output to foreign output, all denominated in their respective currencies. This is analogous to the purchasing power parity condition, where the exchange rate is equivalent to the ratio of the prices of a basket of goods in their respective currencies. The null hypothesis is that the coefficients β_1 and β_2 are equal to zero, in which case both relative money supply and relative real output are not related to the exchange rate. The alternative hypothesis is that one or both coefficients are not equal to zero, in which case one or both of the independent variables are related to the exchange rate.

Review of Related Literature

Economic theory postulates that the exchange rate between two countries should depend on economic variables such as interest rates, inflation, prices, and so forth. Yet research has shown that this may not be the case. Early studies found that theoretical models fit the data in-sample. However, in a landmark study, Meese and Rogoff (1983) reported that various economic models failed to outperform the out-of-sample forecasting accuracy of a naïve random walk model. They examined three structural models, which included money supply, output, interest rates, inflation, and trade balances, and a benchmark random walk model, where the current spot rate predicts all future spot rates. They confirmed that none of the models achieved a lower root mean squared error (RMSE) than the random walk model at any horizon. They thus concluded that a random walk model performs as well as any estimated model at one to 12-month horizons. Many researchers have attempted to overturn or explain these results during the succeeding decade but failed to convincingly do so (Frankel & Rose, 1995).

Interest in this line of research was rekindled when Mark (1995) presented evidence of long-horizon predictability in exchange rates. Mark assumed that the exchange rate deviates from its fundamental value and hypothesized that the log exchange rate returns to its fundamental value over time so that its behavior can be characterized by deviations from a benchmark monetary model. The fundamental value that he used is based on the flexible price monetary model. He found that for the German, Japanese, and Swiss exchange rates, the forecasting model has lower RMSE compared to a random walk model at many horizons and concluded that there is significant evidence of forecasting power (Engel, 2014).

Mark's (1995) results were subsequently scrutinized and debated. On the one hand, Kilian (1999) showed that Mark's findings were not robust enough to extend the sample period up to Q4 1997. He also showed that the bootstrap procedure Mark used was not entirely correct and may result in spurious inference. After adjusting the test procedure, he obtained very limited support for the monetary model and no evidence of increased long-horizon predictability. Faust et al. (2003) argued that the favorable evidence of long-horizon exchange rate predictability is present in only a two-year window of data vintages around that originally used. Had Mark constructed his dataset at almost any other time, he would have gathered considerably less evidence of predictability.

On the other hand, a number of studies found that economic fundamentals and exchange rates are cointegrated (Engel, 2014), that is, there is a long-run relationship between at least two of them. Groen (2000) examined a panel of quarterly data consisting of 14 major currencies from Q1 1973 to Q4 1994 and rejected the null hypothesis that the exchange rate is not cointegrated with relative log money supplies and relative log outputs. Mark and Sul (2001) performed a panel cointegration test and observed that exchange rates are cointegrated with monetary fundamentals. They also used panel regression to estimate the model used to make forecasts and concluded that monetary fundamentals contain significant predictive power for future exchange rate movements. Rapach and Wohar (2002) found cointegration between the U.S. dollar exchange rates and economic fundamentals of 14 countries with samples of over 100 years. Groen (2005) examined a small panel of exchange rates from Q1 1975to Q4 2000and reported that the monetary model generally produces forecasts with lower RMSE than a random walk at horizons of 12-16 months. Engel et al. (2008) confirmed and updated Mark and Sul's (2001) study, using quarterly data beginning Q1 1973 to produce 1-quarter and 16-quarter forecasts from Q1 1983 to Q1 2005. They found that the monetary model produces significantly better out-of-sample forecasts at the 16-quarter horizon than either the driftless random walk or the random walk with drift. Moreover, McCracken and Sapp (2005) suggested that the previous studies' inability to detect predictive ability may be due to the statistics used and how they were used. They found that using newer test statistics offers more power to reject the random walk using the same sample and procedure as Kilian (1999).

One of the few studies that include emerging markets in the evaluation of the predictive ability of the monetary model is Cerra and Saxena (2010). Using annual data from 98 countries, they performed in-sample analysis using panel cointegration tests and estimation to look for stable long-run relationships among exchange rates and monetary fundamentals. They obtained strong evidence for cointegration with the monetary models dominating the random walk model in out-of-sample prediction for 51 out of 52 total results and forecasting performances that were statistically significant for 50 out of 52 results. They found that the outperformance of the structural models is not driven by particular regions or income groups (i.e., developed or emerging markets) that have some peculiar economic feature.

In summary, Meese and Rogoff (1983) did not find a relationship among the variables, concluding that a random walk model performs as well as any estimated model at one to 12-month horizons. Mark (1995) found evidence of long-horizon predictability in exchange rates, suggesting a relationship between economic fundamentals and exchange rate movements. Kilian (1999) and Faust et al. (2003) challenged Mark's findings, indicating limited support for the monetary model and no evidence of increased long-horizon predictability. However, Groen (2000), Mark and Sul (2001), Rapach and Wohar (2002), Groen (2005), Engel et al. (2008), McCracken and Sapp (2005), and Cerra and Saxena (2010) found a relationship between economic fundamentals and exchange rates, with various studies confirming cointegration and the predictive power of monetary models over random walk models.

This paper brings important insights to the study of foreign exchange and emerging markets. Although most research has focused on developed markets, this paper looks at how economic factors like output, income, interest rates, and inflation affect exchange rates in emerging markets. It improves upon previous studies by including more countries, longer data timelines, and modern analysis methods.

Data

The data consists of a panel of quarterly observations of the spot exchange rates expressed in USD per FCU, money supply, and real output for 27 countries for the period 2001Q4 to 2020Q2, downloaded mainly from the International Financial Statistics (IFS) database of the International Monetary Fund (IMF). Twelve of the countries were classified as developed markets, whereas 15 were classified as emerging markets based on the data and definitions of the World Economic Outlook (WEO) of the IMF in 2001. The countries defined as such in 2001 remained so throughout the sample period; that is, no emerging market became developed or vice-versa. Emerging markets that were able to attain developed status within the sample period, such as China and the Czech Republic, were excluded. The sample period was limited by what was available in the IFS-IMF database. If there were missing data for a particular country-variable within the sample period, the entire country-variable dataset from the IMF was replaced with that from the Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of St. Louis. Countries that did not have complete data from either IMF or FRED were omitted. Raw data were not seasonally adjusted except for money supply for Indonesia, and real output for Russia. The data were seasonally adjusted using the U.S. Census Bureau's X12 method. The countries included as well as their descriptive statistics are listed in Table 1, arranged in decreasing 2001 per capita GDP.

Preliminary analysis of the data shows that GDP per capita is positively correlated with changes in the spot rate with a correlation coefficient of 0.60 and negatively correlated with changes in money supply and real output with correlation coefficients of -0.64 and -0.74, respectively. This means that, on average, developed markets had greater currency appreciation but slower growth in money supply and real output compared to emerging markets over the sample period.

The data were first examined for stationarity. A stationary series is a series with a constant mean, constant variance, and constant autocovariance for each given lag. This is important because the use of nonstationary data can lead to spurious regression. The results of the stationary tests are also relevant to the succeeding tests and analyses. If a nonstationary time series becomes stationary after taking its first differences, then it is said to be integrated of order one, denoted as I(1). An I(0) series is a stationary series, whereas an I(1) series contains one unit root. Because the variables are expressed in logarithmic terms, the first difference represents the percentage change in those variables.

Each of the time series variables was tested for stationarity using the Augmented Dickey-Fuller (ADF)

Table 1. *Data and Descriptive Statistics.*

	GDP	Δs	SD(Δs)	Δm	SD(Δm)	Δy	SD(Δy)
Switzerland	60,666	3.3811	9.2991	4.3989	1.9754	1.9389	1.2832
Norway	56,941	0.6553	11.9141	5.9438	3.6012	1.4905	2.0890
Denmark	49,364	1.6274	9.8366	5.7353	7.5155	1.3846	1.6962
Canada	41,952	1.4078	8.6051	7.2311	1.5836	1.9770	1.2112
Sweden	41,668	1.0952	11.3224	6.9969	3.4603	2.1584	1.8057
Australia	40,052	2.2741	11.8648	8.9710	3.3753	2.7976	0.8497
U.K.	39,321	-0.4805	9.4255	5.8915	3.8668	1.6258	1.1608
Japan	36,285	1.6710	10.5466	1.8406	0.8036	0.9192	2.0362
Euro	35,744	1.6689	9.8412	4.9555	1.7574	1.1912	1.2146
New Zealand	32,603	3.0259	11.8845	7.7429	2.1824	2.8556	1.4601
Israel	30,306	1.6551	7.9534	5.4430	6.8011	3.5980	1.2746
Korea	23,919	0.9703	9.1317	7.5056	1.7987	3.6622	1.6900
Hungary	20,471	0.4901	14.2757	7.8369	3.9633	2.4274	2.0767
Croatia	19,416	1.6796	10.0785	5.9077	5.2610	1.8744	2.6336
Mexico	17,556	-3.7463	10.2467	9.3992	2.7106	2.0980	1.9947
Poland	16,611	1.0135	14.3219	8.7661	2.6910	3.9370	1.7965
Chile	15,440	0.0545	11.2032	7.9481	5.7437	3.7650	1.7824
Russia	15,338	-3.2818	13.4159	19.8534	6.3101	3.1742	2.9604
Romania	12,834	-1.1915	11.0456	15.3409	8.6417	3.9238	2.9308
Costa Rica	12,728	-2.8653	4.7987	11.6731	5.7749	3.9138	1.7167
Brazil	11,668	-1.7062	17.2787	12.6521	2.9113	2.3682	2.4005
South Africa	10,193	-0.1416	15.2501	10.5072	3.8746	3.3136	2.5553
Thailand	10,054	2.2729	6.2278	6.5727	2.1112	3.9519	3.5537
Colombia	9,028	-1.3275	13.8073	11.9385	3.1239	3.9411	1.7435
Indonesia	5,870	-1.3029	9.3634	11.3604	3.1781	5.3115	0.6118
Philippines	4,553	0.0768	5.4674	10.6373	4.0458	5.5461	1.5850
India	2,435	-1.8735	7.4773	13.6916	2.8844	7.0478	2.0157
Correlation	1.0000	0.5986	-0.0066	-0.6435	-0.1473	-0.7413	-0.3736
All Countries	24,927	0.1758	11.0740	8.9091	4.5971	2.4688	3.2178
Developed	40,735	1.5672	10.2607	6.2066	3.8761	1.6255	2.6541
Emerging	12,280	-0.9402	11.6602	11.0766	4.8384	3.1450	3.5723

GDP = Gross Domestic Product per capita 2001, constant prices, Purchasing Power Parity, 2017 International Dollars
S = spot rate - Exchange Rates, U.S. Dollar per Domestic Currency, End of Period
M = money supply - Monetary and Financial Accounts, Monetary Aggregates, Broad Money, Domestic Currency
Y = real output - National Accounts, Expenditure, GDP, Real, Spliced Historical Series, Seasonally Adjusted, Domestic Currency
Δx = average quarterly change annualized = $\frac{x_1 - x}{x} * 100 * 4$
SD = quarterly standard deviation annualized = $sd * \sqrt{4}$
Correlation = versus GDP

test. The objective of the basic Dickey-Fuller test is to test the hypothesis that $\phi = 1$ in

$$y_t = \phi y_{t-1} + u_t$$

against the one-sided alternative that $\phi < 1$. That is H_0: the series contains a unit root versus H_1: the series is stationary. In practice, the test used for ease of computation and interpretation is

$$\Delta y_t = \psi y_{t-1} + u_t$$

so that a test of $\phi = 1$ is equivalent to a test of $\psi = 0$ since $\phi - 1 = \psi$. The test is then augmented using multiple lags of the dependent variable to ensure that u_t is not autocorrelated, which could invalidate the test. The optimal number of lags of the dependent variable may be determined by selecting the one that minimizes the value of some information criteria. In this case, the Akaike, Schwarz and Hannan-Quinn information criteria were all used. The results of the unit root tests are presented in Table 2.

Table 2. *Results of ADF Test for Unit Roots*

Stationary In Levels										Stationary In First Differences									
Variable	Money			Output			Spot			Variable	Money			Output			Spot		
Criterion	A	S	H	A	S	H	A	S	H	Criterion	A	S	H	A	S	H	A	S	H
AUS	✓									AUS	✓	✓	✓	✓	✓	✓	✓	✓	✓
BRA										BRA	□	✓	□	✓	✓	✓	✓	✓	✓
CAN										CAN	✓	✓	✓	✓	✓	✓	✓	✓	✓
CHL										CHL	✓	✓	✓	✓	✓	✓	✓	✓	✓
COL										COL	□	✓	□	□	□	□	✓	✓	✓
COS	✓	✓	✓				✓	✓	✓	COS	□	□	□	✓	□	□	✓	✓	✓
CRO										CRO	✓	✓	✓	✓	✓	✓	✓	✓	✓
DNK										DNK	✓	✓	✓	✓	✓	✓	✓	✓	✓
EUR							✓	✓	✓	EUR	✓	✓	✓	□	✓	✓	✓	✓	✓
HUN		✓								HUN	□	✓	□	✓	✓	✓	✓	✓	✓
IND										IND	□	□	□	✓	✓	✓	✓	✓	✓
INO										INO	□	✓	✓	✓	✓	✓	✓	✓	✓
ISR										ISR	✓	✓	✓	✓	✓	✓	✓	✓	✓
JPN										JPN	✓	✓	✓	✓	✓	✓	✓	✓	✓
KOR										KOR	✓	✓	✓	✓	✓	✓	✓	✓	✓
MEX										MEX	✓	✓	✓	✓	✓	✓	✓	✓	✓
NEZ							✓	✓	✓	NEZ	✓	✓	✓	✓	✓	✓	✓	✓	✓
NOR										NOR	✓	✓	✓	✓	✓	✓	✓	✓	✓
PHL										PHL	✓	✓	✓	✓	✓	✓	✓	✓	✓
POL										POL	✓	✓	✓	□	✓	✓	✓	✓	✓
ROU	✓	✓	✓							ROU	□	✓	✓	□	✓	✓	✓	✓	✓
RUS	✓	✓	✓							RUS	✓	✓	✓	✓	✓	✓	✓	✓	✓
SAF	✓	✓	✓							SAF	✓	✓	✓	□	□	□	✓	✓	✓
SWE										SWE	✓	✓	✓	✓	✓	✓	✓	✓	✓
SWZ										SWZ	□	□	□	✓	✓	✓	✓	✓	✓
THA										THA	□	□	□	✓	✓	✓	✓	✓	✓
UKD										UKD	□	✓	✓	□	□	□	✓	✓	✓

✓= stationary; A = Akaike information criterion; S = Schwarz information criterion; H = Hannah-Quinn information criterion

When the variables were tested in levels, the number of countries out of 27 that had stationary variables for all three information criteria were four for money supply, none for output, and three for spot rates. When the variables were tested in first differences, the numbers went up to 17 for money supply, 20 for output, and all 27 for spot rates. Therefore, all three variables are generally integrated of order one and stationary in the first differences.

The flexible price monetary models of exchange rates were evaluated using both in-sample and out-of-sample analysis. Two in-sample tests were done: first, by estimating time series and panel regression models and second, by testing for cointegration both per country and for the entire panel data set. Historically, the results of in-sample regression have been found to conflict with those of out-of-sample regression, with the former finding significant relationships where the latter did not. Thus, the cointegration test may shed more light on the long-run relationships of the variables. Despite its shortcomings, however, the in-sample regressions would provide an interesting point of comparison for the cointegration tests and the out-of-sample regressions.

Meanwhile, the out-of-sample test involves dividing the data set into two, estimating the coefficients from a regression for each model using the first half of the sample period, and then using the coefficients together with the actual future values of the exogenous variables to forecast the exchange rates in the second half of the sample period. The deviations of the forecasts of the exchange rates from their actual values were then obtained for each model and compared with each other. The ability of the models to forecast the direction of change in the exchange rates was also evaluated.

Methods

In-sample Tests: OLS Estimation and Cointegration Tests

The first in-sample test is the estimation of time-series and panel regression models. Once the data for each country were confirmed to be stationary in the first differences, a time-series regression model for each country may be estimated:

$$\Delta s = \alpha + \beta_1 \Delta m_t + \beta_2 \Delta y_t + u_t$$

where Δs is the change in the nominal exchange rate, Δm is the change in log money supply relative to the US, Δy is the change in log real output relative to the U.S., and t is the time period.

A panel regression model was also estimated for the entire data set. Panel data combines a time series of cross-section observations and offers more informative data, more variability, more degrees of freedom, more efficiency, and less collinearity. This is especially relevant to this study because the frequency of the data is quarterly, limiting the data points to four per year for a total of 75 data points per time series. There are two panel regression models that are often used: the fixed effects model (FEM) and the random effects model (REM). The FEM assumes that the coefficients of the regressors are the same across countries and over time but allows the intercept to differ across countries:

$$\Delta s = \alpha_i + \beta_1 \Delta m_{it} + \beta_2 \Delta y_{it} + u_{it}$$

where i is the ith country. Note the subscript i on the intercept term suggests that the intercepts of each country may be different to capture the unique features of each country. On the other hand, the REM assumes that the intercept is a random variable with a mean value of α (without subscript i), and the intercept for an individual country can be expressed as:

$$\alpha_i = \alpha + \varepsilon_i \qquad i = 1,2,\dots,N$$

where ε_i is a random error with a mean value of zero and variance of σ^2. Thus, the intercept is the mean value common to all countries, and the individual differences in the intercept are reflected in the error term ε_i. The random effects model can be expressed as:

$$\Delta s = \alpha + \beta_1 \Delta m_{it} + \beta_2 \Delta y_{it} + \varepsilon_i + u_{it}$$

$$= \alpha + \beta_1 \Delta m_{it} + \beta_2 \Delta y_{it} + w_{it}$$

where $w_{it} = \varepsilon_i + u_{it}$.

The fixed effects model for panel regression is used for the analysis of economic variables across different countries when each country has time-invariant characteristics that influence these variables. For example, if factors like culture, political institutions, or historical legacies have a consistent and unchanging influence on exchange

Table 3. *Panel Regression Model Tests*

A. Redundant Fixed Effects Test				**B. Hausman Test**			
Pool	F-Stat	d.f.	pval	Pool	Chi-Sq. Stat	d.f.	pval
ALL	1.403753	-261,888	0.0849	ALL	0.416156	2	0.8121
DEV	0.604099	-11,838	0.8263	DEV	0.087466	2	0.9572
EMR	0.783826	-141,048	0.6877	EMR	0.126504	2	0.9387

rates, money supply, and output for each country, then fixed effects are appropriate because the fixed effects model captures these country-specific effects that remain constant over time. On the other hand, the random effects model is used when common, time-varying factors affect these variables across all countries. For example, if factors that influence exchange rates, money supply, and output similarly across all countries vary over time, such as global economic trends or shocks affecting multiple countries, the random effects model is appropriate because it captures these common time-varying effects that are shared across all countries. Model specification tests can help determine which is the more appropriate model. In this case, two tests were performed. First, an FEM was assumed and tested for all developed and emerging markets using the redundant fixed effects test, which is a test for joint significance of the cross-section effects with the null hypothesis that they are redundant. The results of this first test, presented in Table 3A, show that the null of redundant fixed effects cannot be rejected for the three types of markets. Therefore, an REM may be more appropriate. To verify this, REM was assumed and tested for all developed and emerging markets using the Hausman test, which tests the assumption that the random effects are uncorrelated with the explanatory variables with a null hypothesis of no correlation, so that REM is preferable. The results of this second test, presented in Table 3B, show that the null of no correlation cannot be rejected for the three types of markets, confirming that the REM is the more appropriate model. Therefore, the panel regression model was estimated using the REM.

The second in-sample test is the test for cointegration. Cointegration implies a long-run or equilibrium relationship between cointegrated variables. A set of nonstationary variables is cointegrated if their linear combination is stationary. The linear combination cancels out the stochastic trends in the two series. Therefore, the three variables that are already confirmed to be integrated may be tested for cointegration by checking if they become stationary when linearly combined. Two tests of cointegration are used for individual countries: the Engel-Granger test, with the change in the exchange rate as a dependent variable, and the Johansen test.

The Engel-Granger test is an ADF unit root test applied to the residuals of the regression equation using critical values obtained by Engel and Granger (1987). The null hypothesis is that the residuals are nonstationary, which implies no cointegration, against the alternative that they are stationary, which implies cointegration. The number of lagged differences to include in the test regression is determined using the Schwarz information criterion, and the degrees of freedom of the standard error estimate were adjusted when forming the ADF test statistics. No trend variable was assumed for the cointegrating equation.

The Johansen test involves setting up a vector autoregression (VAR) model that is then transformed into a vector error correction model (VECM). A linear deterministic trend is included in the data to capture the growth in money supply and real output over time, whereas an intercept with no trend was included in the cointegrating equation. The trace statistic λ_{trace} is reported where the null is that the number of cointegrating vectors is less than or equal to *r* against an unspecified alternative that there are more than *r*. For example, if there are three variables and "at most = 0" is significant, reject the null so there is at least one and at most three cointegrating relationships.

Similar to the advantages of panel regression models over time series regression models, panel cointegration tests may have greater power than individual cointegration tests. Panel cointegration tests were performed using the Pedroni (1999) test, which is essentially a collection of seven unit root tests based on the Engel-Granger two-step cointegration test. These seven tests can be grouped into two. The first four of the statistics are based on pooling along what is known as the "within-dimension" and are constructed by summing both the numerator and the denominator terms over the cross-section or country dimension separately. The other three statistics are based on pooling along what is known as the "between-dimension" and are constructed by first dividing the numerator by the denominator terms prior to summing over the cross-section dimension. The null hypothesis for all the tests is that the residuals of the cointegrating vectors contain unit roots, implying no cointegration.

One important limitation of these tests is that they assume the panel data are cross-sectionally independent, that is, variables in the same cross-section are not correlated. However, this is unlikely to be the case for our variables—money, output, and exchange rates—because they are all relative to the U.S. To control for cross-sectional dependence, period effects were removed by deducting the cross-sectional means from the observations before performing the panel regressions (Pedroni, 1999).

Out-of-Sample Test

The out-of-sample predictions of different specifications of the monetary model were compared with those from a random walk both for each country and for combined data. The estimated coefficients from a regression of the model using data from the first half of the sample period from 2001Q4 to 2011Q2, together with future values of the fundamentals, were used to forecast the exchange rates for each quarter in the second half of the sample period from 2011Q3 to 2020Q2. The forecasting ability of the models was gauged using the Theil ratio, which is the ratio of each model's root mean square error (RMSE) to that of the benchmark random walk, that is, (RMSE model/RMSE benchmark) where

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(\hat{y}_i - y_i)^2}{n}}$$

and $\hat{y}_i$ = forecast values, y_i = actual values, n = number of observations. The lower the RMSE, the better the model. The Theil ratio will be less than one when the RMSE of the monetary model is less than that of the benchmark random walk model. The significance of the single-country Theil ratios will be assessed using the Diebold-Mariano Test. The null hypothesis is that the accuracy of two competing forecasts is equal (Diebold-Mariano, 1995).

Each model is estimated over an initial period using actual values of the fundamentals, so they are evaluated not as forecasting models for earning profits but as determinants of exchange rates. The one-year-ahead forecast errors are obtained from the following four models. ^ denotes the intercountry difference, for example, $\Delta\hat{m}_t = (m_t - m_{t-1}) - (m_t^* - m_{t-1}^*)$:

Model 1: Random walk

$$s_{i,t+1}^e = s_{i,t} \tag{4.9}$$

Model 2: Monetary model in levels

$$s_{i,t+1}^e = \alpha + \beta_1 \hat{m}_{i,t+1} + \beta_2 \hat{y}_{i,t+1} \tag{4.10}$$

Model 3: Monetary model in growth rates using estimated coefficients

$$s_{i,t+1}^e = s_{i,t} + \gamma_0 + \gamma_1(\Delta\hat{m}_{i,t+1}) + \gamma_2(\Delta\hat{y}_{i,t+1}) \tag{4.11}$$

Model 4: Monetary model in growth rates using theoretical coefficients

$$s_{i,t+1}^e = s_{i,t} + (\Delta\hat{m}_{i,t+1} - \Delta\hat{y}_{i,t+1}) \tag{4.12}$$

In Model 3, a set of regressions for the monetary model in growth rates is estimated, pooling the coefficients on money and output from each group, indicating country-fixed effects. These estimates are then used to construct the out-of-sample forecasts. In Model 4, the values of one and minus one are imposed as the coefficients of money growth and output growth, respectively, whereas the intercept is set to zero. According to Cerra and Saxena (2010), differenced models such as these "can have a smaller bias in the presence of structural breaks and can mitigate the bias due to serial correlation of the error terms" (p. 15). They found these two specifications to be the best overall models in terms of the lowest RMSE. Model 3 did best at the one-year horizon, whereas Model 4 did best at the five-year horizon. Estimates of Model

Table 4. *Single Country Estimates of Model 2:* $s^e_{i,t+1} = \alpha + \beta_1 \hat{m}_{i,t+1} + \beta_2 \hat{y}_{i,t+1}$

	α	SE(α)	pval(α)	β_1	SE(β_1)	pval(β_1)	β_2	SE(β_2)	pval(β_2)
AUS	-4.3852	2.1068	0.0446	-1.7289	0.1940	0.0000*	2.2412	0.6667	0.0018*
BRA	-2.7746	2.7520	0.3201	-1.0680	0.2149	0.0000*	0.9726	0.7582	0.2078
CAN	-2.0892	3.1592	0.5126	-2.8878	0.3089	0.0000*	3.8824	1.3873	0.0082*
CHL	-7.5352	0.4172	0.0000	-0.3063	0.2767	0.2757	-1.2410	0.2071	0.0000*
COL	-9.0256	0.9286	0.0000	-0.5930	0.2642	0.0310*	0.0611	0.6919	0.9301
COS	-5.3453	0.1579	0.0000	0.6416	0.0376	0.0000*	-1.0177	0.1504	0.0000*
CRO	9.9648	1.5300	0.0000	-1.0125	0.1234	0.0000*	-1.4537	0.3351	0.0001*
DNK	-6.0858	3.5497	0.0950	-0.8849	0.2815	0.0033*	1.8486	0.8474	0.0358*
EUR	-8.1936	1.5834	0.0000	-1.0131	0.7646	0.1935	4.6989	0.8144	0.0000*
HUN	-3.8887	0.5803	0.0000	-0.7376	0.1433	0.0000*	-1.9467	0.7361	0.0120*
IND	-4.1967	0.3952	0.0000	-0.3478	0.3581	0.3379	0.4958	0.5703	0.3904
INO	-7.6025	0.8302	0.0000	-0.5350	0.3193	0.1025	0.9157	0.5078	0.0797
ISR	1.0657	1.1064	0.3419	0.2978	0.0915	0.0025*	-0.7851	0.2065	0.0005*
JPN	1.0838	1.7178	0.5321	0.0548	0.2747	0.8431	2.6204	1.3786	0.0654
KOR	-5.4828	1.8207	0.0047	0.6913	0.7149	0.3400	-0.5780	0.6271	0.3628
MEX	-0.0445	1.4556	0.9758	0.7622	0.1728	0.0001*	-2.3658	1.0522	0.0308*
NEZ	20.2182	3.4572	0.0000	-2.6993	0.3233	0.0000*	-1.5231	0.6830	0.0321*
NOR	-6.7354	4.6854	0.1592	-1.8895	0.6334	0.0051*	2.8262	1.2504	0.0299*
PHL	-2.3790	0.3101	0.0000	0.0115	0.2610	0.9651	-0.8293	0.2978	0.0085*
POL	1.8264	2.0465	0.3781	-0.7040	0.6251	0.2675	-0.2180	0.9786	0.8250
ROU	3.6839	1.4071	0.0129	0.0627	0.0779	0.4260	-1.0486	0.3550	0.0055*
RUS	-3.7428	0.0849	0.0000	0.2888	0.0742	0.0004*	-2.1835	0.4604	0.0000*
SAF	-6.8594	1.7850	0.0005	-2.2545	0.6897	0.0024*	5.1709	1.7267	0.0049*
SWE	2.3823	3.8565	0.5406	-1.1872	0.4434	0.0111*	-0.7674	1.5486	0.6232
SWZ	-2.5194	4.6072	0.5879	1.0512	0.2450	0.0001*	-0.1344	0.8863	0.8803
THA	-0.3557	0.1867	0.0647	0.0448	0.1334	0.7388	-1.5277	0.0872	0.0000*
UKD	8.9844	9.8343	0.3670	-0.1857	0.3546	0.6038	-2.3155	2.6445	0.3871

**significant at the 5% level*

2 are presented in Table 4, most of which are highly significant. However, Model 2 has been shown to be nonstationary, so the relationship is likely to be spurious. Estimates of Model 3 are presented in Table 5, most of which are not significant. No estimates are generated for Model 1 and Model 4 because their coefficients are imposed to be either +1 or -1.

The direction of change criterion was used to determine the proportion of forecasts that correctly predict the direction of change of the exchange rate. This was done for both each country and for the combined data. A result significantly greater than 0.50 indicates a better-than-even chance of forecasting the direction of change in the exchange rate. Abhyankar et al. (2005) found that the direction of change metric has economic value in the evaluation of exchange rate forecasts from a fundamental model. It may even be more relevant to trading profitability compared to the RMSE because the latter merely compares the distance between forecasted and actual values, regardless of whether the direction of the forecast is correct.

Table 5. *Single Country Estimates of Model 3:* $s^e_{i,t+1} = s_{i,t} + \gamma_0 + \gamma_1(\Delta\hat{m}_{i,t+1}) + \gamma_2(\Delta\hat{y}_{i,t+1})$

	γ_0	SE(γ_0)	pval(γ_0)	γ_1	SE(γ_1)	pval(γ_1)	γ_2	SE(γ_2)	pval(γ_2)
AUS	0.0291	0.0142	0.0478*	0.3270	0.5883	0.5818	2.0506	1.6178	0.2133
BRA	-0.0026	0.0258	0.9200	-0.5118	0.9083	0.5767	-0.2718	1.4908	0.8564
CAN	0.0128	0.0077	0.1039	-0.2115	0.4996	0.6747	1.8316	1.2415	0.1491
CHL	0.0124	0.0115	0.2891	0.8663	0.2434	0.0011*	0.0353	1.0119	0.9723
COL	0.0081	0.0189	0.6708	0.0918	0.6674	0.8914	-0.0439	1.3119	0.9735
COS	-0.0037	0.0059	0.5359	0.4440	0.1351	0.0023*	-0.7607	0.4352	0.0892
CRO	0.0138	0.0085	0.1146	0.3026	0.3010	0.3216	-1.5682	0.5795	0.0105*
DNK	0.0152	0.0089	0.0943	0.3274	0.2253	0.1552	-0.5039	0.9647	0.6047
EUR	0.0151	0.0092	0.1070	0.2136	0.7509	0.7777	-1.2437	1.5106	0.4159
HUN	0.0223	0.0137	0.1126	1.2007	0.6654	0.0798	-3.5544	1.3824	0.0145*
IND	-0.0120	0.0114	0.2980	-0.1974	0.3840	0.6105	-0.6286	0.5103	0.2262
INO	0.0267	0.0154	0.0927	0.5431	0.4344	0.2195	1.5446	1.1504	0.1880
ISR	0.0093	0.0083	0.2676	0.2012	0.1427	0.1675	0.7839	0.9410	0.4105
JPN	0.0163	0.0105	0.1291	0.1384	0.5665	0.8084	-1.5793	0.9095	0.0913
KOR	0.0053	0.0101	0.6052	-0.2302	0.5370	0.6708	0.1865	1.0278	0.8570
MEX	-0.0097	0.0089	0.2858	-0.3690	0.4414	0.4088	0.3608	0.8370	0.6690
NEZ	0.0149	0.0115	0.2041	-0.6016	0.6334	0.3487	-0.0559	1.0496	0.9578
NOR	0.0117	0.0108	0.2854	-0.1352	0.5946	0.8215	1.1855	0.8392	0.1666
PHL	0.0071	0.0068	0.3079	-0.0065	0.2281	0.9773	0.3738	0.6886	0.5907
POL	0.0251	0.0166	0.1394	0.4625	0.7798	0.5570	1.8603	1.0787	0.0934
ROU	-0.0004	0.0128	0.9778	0.0065	0.1995	0.9743	-0.5484	0.6022	0.3688
RUS	-0.0274	0.0126	0.0361*	-0.3510	0.2580	0.1824	-1.6860	0.5368	0.0034*
SAF	0.0252	0.0191	0.1966	-0.4005	0.6137	0.5183	2.3475	1.1082	0.0413*
SWE	0.0127	0.0109	0.2530	-0.1108	0.4942	0.8238	-0.4644	1.4825	0.7559
SWZ	0.0177	0.0089	0.0542	0.2299	0.5101	0.6550	0.5999	1.4212	0.6755
THA	0.0070	0.0057	0.2250	-0.2007	0.3051	0.5150	-0.3180	0.3885	0.4186
UKD	0.0095	0.0090	0.3004	0.9943	0.3577	0.0087*	-0.1201	1.6496	0.9424

**significant at the 5% level*

Results

The results of the single-country regressions, presented in Table 6a, are inconclusive. Out of 27 countries, only five have statistically significant money supply, and five have statistically significant real output. The results of the panel regression are presented in Table 6b. For all countries taken together, money supply was significantly positive, whereas real output was negative but not significant. When results were segregated into developed and emerging markets, both money supply and real output were positive but not significant for developed markets, while money supply was significantly positive and real output was significantly negative for emerging markets. Therefore, based on the panel regression results, changes in money supply are directly related, and changes in real output are inversely related to nominal spot exchange rates, which are in line with the flexible price monetary model but only for emerging markets.

Table 6A. *Single Estimates* $\Delta s = \alpha + \beta_1 \Delta m_t + \beta_2 \Delta y_t + u_t$

	α	se(α)	pval(α)	B_1	se(β_1)	pval(β_1)	B_2	se(β_2)	pval(β_2)
AUS	0.0047	0.0080	0.5569	-0.1201	0.4251	0.7784	0.7753	1.5673	0.6224
BRA	-0.0134	0.0142	0.3479	-0.2500	0.3324	0.4546	-1.0472	0.9243	0.2612
CAN	0.0006	0.0060	0.9234	-0.1729	0.4559	0.7056	0.9095	1.2727	0.4772
CHL	0.0025	0.0065	0.7024	0.7598	0.1438	0.0000*	0.3539	0.5466	0.5194
COL	-0.0077	0.0118	0.5200	-0.2131	0.5768	0.7129	0.6321	0.4718	0.1846
COS	-0.0031	0.0034	0.3594	0.3983	0.0971	0.0001*	-0.3806	0.3405	0.2675
CRO	0.0045	0.0053	0.3985	0.2293	0.1157	0.0513	-0.9924	0.5231	0.0619
DNK	0.0035	0.0060	0.5624	0.2105	0.1606	0.1943	-0.3756	0.5700	0.5121
EUR	0.0059	0.0059	0.3256	0.5072	0.5744	0.3802	-1.2703	0.7168	0.0806
HUN	0.0017	0.0078	0.8311	0.6964	0.4717	0.1443	-0.7480	1.1302	0.5102
IND	-0.0167	0.0059	0.0057*	0.1255	0.3498	0.7209	-1.1394	0.5255	0.0336*
INO	0.0004	0.0150	0.9768	0.3829	0.4605	0.4085	0.1753	1.2356	0.8876
ISR	0.0058	0.0047	0.2240	0.2675	0.1646	0.1087	0.6641	0.6910	0.3399
JPN	0.0024	0.0077	0.7524	0.2995	0.4396	0.4979	-0.9107	0.5184	0.0833
KOR	0.0014	0.0060	0.8221	-0.0821	0.4229	0.8467	0.1520	0.5985	0.8002
MEX	-0.0156	0.0094	0.0995	-0.2540	0.5146	0.6231	0.6858	0.3224	0.0369*
NEZ	0.0040	0.0067	0.5465	-0.4292	0.3343	0.2033	0.0302	0.7979	0.9699
NOR	-0.0013	0.0072	0.8554	-0.0821	0.3019	0.7865	0.3796	0.7840	0.6298
PHL	0.0020	0.0038	0.5915	0.2769	0.1379	0.0485*	-0.1693	0.2730	0.5371
POL	0.0149	0.0075	0.0486*	0.8339	0.5155	0.1102	1.8758	1.1386	0.1039
ROU	-0.0051	0.0078	0.5150	0.0062	0.1923	0.9745	-0.2485	0.3007	0.4113
RUS	0.0072	0.0103	0.4898	0.7299	0.3804	0.0591	-2.9149	0.8011	0.0005*
SAF	-0.0130	0.0111	0.2454	-0.9323	0.4264	0.0321*	1.1348	0.6788	0.0990
SWE	0.0010	0.0070	0.8822	-0.2273	0.3392	0.5050	0.0395	0.7384	0.9575
SWZ	0.0067	0.0048	0.1681	0.2401	0.2708	0.3782	-0.4323	0.8960	0.6309
THA	0.0034	0.0033	0.3053	-0.1624	0.2251	0.4732	-0.2917	0.1124	0.0115*
UKD	-0.0009	0.0057	0.8732	0.8524	0.3366	0.0135*	-0.3720	0.1527	0.0174*

**significant at the 5% level*

Table 6B. *Panel Estimates* $\Delta s = \alpha_i + \beta_1 \Delta m_{it} + \beta_2 \Delta y_{it} + u_{it}$

	β_1	se(β_1)	pval(β_1)	β_2	se(β_2)	pval(β_2)
ALL	0.2756	0.0992	0.0055*	-0.2955	0.2324	0.2037
DEV	0.2104	0.1218	0.0843	0.0277	0.3784	0.9416
EMR	0.2887	0.1129	0.0107*	-0.4768	0.2391	0.0464*

**significant at the 5% level*

Table 7. *Cointegration Tests*

	Engel-Granger		Johansen Trace Statistics		
	ADF	p-val	max 0	max 1	max 2
AUS	-2.0225	0.4918	0.0122*	0.3137	0.0506
BRA	-1.1867	0.8542	0.0015*	0.0052*	0.0035*
CAN	-2.1312	0.4365	0.0048*	0.0329*	0.0324*
CHL	-1.2137	0.8465	0.0006*	0.0051*	0.0042*
COL	0.0083	0.9874	0.0010*	0.0341*	0.0337*
COS	-1.5322	0.7310	0.0007*	0.0708	0.3117
CRO	-3.7295	0.0208*	0.0249*	0.1164	0.1229
DNK	-3.1767	0.0770	0.1644	0.7289	0.4855
EUR	-3.2259	0.0693	0.0051*	0.6505	0.2208
HUN	-1.7100	0.6497	0.3754	0.4503	0.6866
IND	-2.4837	0.2737	0.0429*	0.2569	0.4036
INO	-2.5237	0.2575	0.1314	0.7679	0.2250
ISR	-5.0772	0.0004*	0.0498*	0.2754	0.2719
JPN	-1.0221	0.8948	0.6091	0.5396	0.9490
KOR	-2.5763	0.2372	0.0927	0.1588	0.0358*
MEX	-4.2057	0.0056*	0.1921	0.1837	0.1440
NEZ	-3.1125	0.0882	0.3707	0.3777	0.1702
NOR	-1.6807	0.6638	0.0220*	0.2130	0.6536
PHL	-3.6036	0.0289*	0.2957	0.8012	0.6090
POL	-2.3620	0.3259	0.1149	0.2671	0.1060
ROU	-1.4453	0.7668	0.2829	0.5635	0.5011
RUS	-1.6365	0.6845	0.0009*	0.0769	0.1518
SAF	-3.5073	0.0362*	0.0089*	0.0900	0.9620
SWE	-2.8362	0.1518	0.1708	0.2220	0.4935
SWZ	-2.7465	0.1783	0.0010*	0.0493*	0.0851
THA	-3.6963	0.0226*	0.3495	0.4195	0.0599
UKD	-0.8843	0.9205	0.2810	0.2882	0.0408*

**significant at the 5% level*

Table 7 presents the results of the Engel-Granger and Johansen cointegration tests. The Engel-Granger test found a significant relationship in only six out of 27 countries, whereas the Johansen test found at least one cointegrating relationship in 14 out of 27 countries. Of the 14, six were developed markets and eight were emerging markets. Only five out of 27 countries exhibited two or more cointegrating relationships.

Table 8. *Panel Cointegration Test*

Panel Cointegration			
	ALL_T	DEV_T	EMR_T
V	0.4341	0.8320	0.1319
RHO	0.0296*	0.1809	0.0417*
PP	0.0001*	0.0019*	0.0041*
ADF	0.0003*	0.0016*	0.0192*
W-V	0.4935	0.8053	0.1399
W-RHO	0.0342*	0.2130	0.0303*
W-PP	0.0001*	0.0038*	0.0027*
W-ADF	0.0001*	0.0014*	0.0129*
G-RHO	0.2712	0.5854	0.1562
G-PP	0.0002*	0.0093*	0.0050*
G-ADF	0.0005*	0.0023*	0.0327*

Demeaned Data			
	ALL_T	DEV_T	EMR_T
V	0.0812	0.2582	0.1153
RHO	0.0161*	0.0763	0.0554
PP	0.0003*	0.0041*	0.0083*
ADF	0.0009*	0.0066*	0.0176*
W-V	0.1152	0.3279	0.1066
W-RHO	0.0003*	0.0010*	0.0394*
W-PP	0.0000*	0.0000*	0.0094*
W-ADF	0.0000*	0.0000*	0.0170*
G-RHO	0.0813	0.0474*	0.3523
G-PP	0.0001*	0.0001*	0.0455*
G-ADF	0.0004*	0.0003*	0.0729

**significant at the 5% level*

The results of these panel cointegration tests for both raw and demeaned data are presented in Table 8. All test statistics except the variance ratio and the group rho statistics were highly significant for both raw and demeaned data for all countries combined. For the demeaned data, developed markets were slightly more significant compared to those of emerging markets, but not enough to distinguish one type of market from the other. Therefore, the null hypothesis that the residuals of the cointegrating vectors contain unit roots is rejected, providing evidence for the cointegration of exchange rates, relative money, and relative output.

The Theil ratios for single-country models are presented in Table 9. Theil ratios less than one are in bold, whereas boxed cells indicate the model with the lowest Theil ratio for a particular country. Countries without boxed cells have Model 1, the Random Walk Model, as the model with the lowest Theil ratio. Model 2, the monetary model in levels, did not beat the random walk in any country. Model 3, the monetary

Table 9. *Single-Country Theil Ratios and Diebold-Mariano Statistics*

	THEIL2	DM2	PVAL2	THEIL3	DM3	PVAL3	THEIL4	DM4	PVAL4
AUS	7.2005	-7.1511	0.0000*	1.2349	-3.5702	0.0011*	1.0617	-0.7576	0.4538
BRA	11.7283	-7.8087	0.0000*	**0.9436**	-2.0185	0.0520	0.8695	0.9300	0.3593
CAN	16.2098	-7.0329	0.0000*	1.1978	-2.1218	0.0412*	1.0506	-0.4815	0.6332
CHL	8.9060	-8.8138	0.0000*	1.0734	-0.7981	0.4302	1.1458	-0.8508	0.4007
COL	8.5529	-7.2229	0.0000*	1.0352	-2.0495	0.0480*	1.0420	-0.8534	0.3993
COS	4.0446	-4.4807	0.0001*	1.0132	-0.1410	0.8887	1.2093	-1.1250	0.2683
CRO	4.8414	-6.7748	0.0000*	1.1567	-1.5797	0.1232	1.1429	-0.9643	0.3415
DNK	4.6030	-5.4092	0.0000*	1.1379	-2.3711	0.0234*	1.2664	-1.4757	0.1490
EUR	9.7079	-7.8449	0.0000*	1.0742	-1.5249	0.1363	**0.9626**	1.2807	0.2087
HUN	5.6193	-5.0840	0.0000*	1.4656	-2.5231	0.0163*	1.0284	-0.3715	0.7125
IND	9.1079	-12.9802	0.0000*	**0.9841**	1.2213	0.2306	**0.9237**	0.8956	0.3769
INO	7.2615	-8.9606	0.0000*	1.0184	-1.3850	0.1751	**0.8927**	0.3346	0.7400
ISR	1.1264	-0.6601	0.5139	1.0000	0.3894	0.6996	**0.9078**	1.5224	0.1377
JPN	6.3030	-8.2963	0.0000*	1.0931	-1.8193	0.0774	1.0322	-0.6431	0.5244
KOR	1.2298	-1.3173	0.1965	1.0360	-0.9464	0.3506	1.0687	-0.6310	0.5323
MEX	2.2914	-4.6233	0.0000*	**0.9750**	0.8341	0.4099	1.0292	-0.4849	0.6308
NEZ	11.7178	-7.0932	0.0000*	1.1033	-1.8019	0.0802	1.0345	-0.5189	0.6071
NOR	7.1269	-6.8174	0.0000*	1.1308	-2.6613	0.0117*	1.0786	-1.1271	0.2674
PHL	12.4880	-5.8598	0.0000*	1.0792	-1.8257	0.0767	**0.9101**	0.6074	0.5476
POL	7.5454	-9.7525	0.0000*	1.0053	-0.0884	0.9301	**0.9633**	0.6977	0.4900
ROU	8.0723	-8.1610	0.0000*	1.0368	-1.7163	0.0950	1.0072	-0.1190	0.9059
RUS	3.8200	-6.6136	0.0000*	**0.9656**	-0.7070	0.4845	0.7634	2.2171	0.0336*
SAF	12.0246	-6.3139	0.0000*	1.2358	-3.5061	0.0013*	1.0308	-0.7918	0.4338
SWE	6.2328	-5.9795	0.0000*	1.1051	-2.1295	0.0403*	1.0921	-1.3947	0.1719
SWZ	6.6477	-9.4332	0.0000*	1.2298	-2.5973	0.0137*	1.0393	-0.4732	0.6390
THA	3.7208	-6.5672	0.0000*	1.0188	-0.4431	0.6604	1.1595	-1.5146	0.1388
UKD	3.1483	-4.4922	0.0001*	1.0924	-1.1138	0.2730	1.0000	-0.0002	0.9998

**significant at the 5% level*
Theil ratios < 1 are in bold, and box indicates the lowest for a particular country.

model using estimated coefficients, beat the random walk in only 4 countries and was the best in only 1 out of 27 countries. Meanwhile, Model 4, the monetary model using theoretical coefficients, beat the random walk in only eight countries and was the best in eight out of 27 countries. The random walk model was the best model in 18 out of 27 countries. Only one model country had a Theil ratio that was significantly less than one at the 5% level: Model 4 for Russia. Therefore, the single-country out-of-sample tests do not provide conclusive evidence to support the predictive ability of the flexible monetary model.

The direction of change statistics for individual countries are shown in Table 10. Direction of change statistics that are greater than 0.50 are in bold, and those that are significantly greater than 0.50 are boxed. Out of the four models applied to 27 countries for a total of 108 forecasts of direction of change, only 37 had a greater than even chance of correctly forecasting the direction of change, and only two were significantly greater at the 5% level—Models 1 and 3, both for Indonesia. There is, therefore, no evidence that any of the models examined on an individual country basis

Table 10. *Proportion of Correct Direction of Change*

	MODEL1	PVAL1	MODEL2	PVAL2	MODEL3	PVAL3	MODEL4	**PVAL4**
AUS	0.3333	0.0438*	**0.5143**	0.8686	0.4571	0.6192	0.3889	0.1862
BRA	0.3714	0.1300	0.3438	0.0766	0.3750	0.1606	0.4688	0.7297
CAN	0.4000	0.2422	0.4118	0.3105	0.4706	0.7371	0.4118	0.3105
CHL	**0.5143**	0.8686	0.4286	0.4059	**0.5714**	0.4059	**0.5429**	0.6192
COL	0.3429	0.0619	0.4571	0.6192	0.3429	0.0619	0.4286	0.4059
COS	**0.5143**	0.8686	**0.5143**	0.8686	**0.5429**	0.6192	**0.6000**	0.2422
CRO	0.4000	0.2422	0.4857	0.8686	0.4571	0.6192	0.4571	0.6192
DNK	0.4571	0.6192	0.4571	0.6192	0.4286	0.4059	**0.5714**	0.4059
EUR	0.4571	0.6192	0.4286	0.4059	0.4286	0.4059	0.4571	0.6192
HUN	0.4000	0.2422	**0.5143**	0.8686	**0.5143**	0.8686	0.4571	0.6192
IND	0.4857	0.8686	**0.5152**	0.8649	0.4848	0.8649	**0.5152**	0.8649
INO	**0.6857**	0.0257*	0.3235	0.0376*	**0.7059**	0.0140*	**0.6176**	0.1736
ISR	0.4000	0.2422	**0.5313**	0.7297	0.4375	0.4882	0.4063	0.2961
JPN	0.3714	0.1300	0.4000	0.2422	0.5143	0.8686	0.4857	0.8686
KOR	0.4000	0.2422	0.4412	0.5009	0.3824	0.1736	0.3529	0.0863
MEX	0.4000	0.2422	**0.5429**	0.6192	0.4286	0.4059	0.4571	0.6192
NEZ	0.3429	0.0619	0.4571	0.6192	0.3429	0.0619	0.3714	0.1300
NOR	0.3429	0.0619	0.3714	0.1300	0.3143	0.0257*	0.4857	0.8686
PHL	**0.5143**	0.8686	0.4412	0.5009	0.4706	0.7371	**0.5588**	0.5009
POL	0.4000	0.2422	0.3714	0.1300	**0.5429**	0.6192	0.4286	0.4059
ROU	0.4571	0.6192	0.4571	0.6192	0.4286	0.4059	0.4571	0.6192
RUS	0.4571	0.6192	**0.5758**	0.3923	**0.5152**	0.8649	**0.6061**	0.2284
SAF	**0.5714**	0.4059	0.4286	0.4059	**0.5143**	0.8686	**0.6000**	0.2422
SWE	**0.5143**	0.8686	0.4286	0.4059	**0.5143**	0.8686	**0.5143**	0.8686
SWZ	0.4000	0.2422	**0.5143**	0.8686	0.3714	0.1300	0.4000	0.2422
THA	0.4571	0.6192	**0.5714**	0.4059	0.4857	0.8686	0.4571	0.6192
UKD	**0.6000**	0.2422	**0.5143**	0.8686	0.6286	0.1300	**0.6286**	0.1300

**significant at the 5% level*
DOC ratios > 0.50 are in bold, while the box indicates significantly > 0.50.

have a greater than even chance of correctly predicting the direction of change of exchange rates.

Because single-country out-of-sample analysis failed to provide conclusive evidence of predictive ability, the data were combined into panel data, grouped into developed and emerging markets, and re-examined. This was done for both raw data and for data demeaned to control for cross-sectional dependence. The panel fit statistics are presented in Table 11.

For the combined raw data, none of the flexible price monetary models outperformed the random walk in terms of the Theil ratio, nor did they correctly predict the direction of change more than half the time. When the combined raw data were grouped into developed and emerging markets, none of the flexible price monetary models outperformed the random walk or correctly predicted the direction of change more than half the time in developed markets. However, Model 3 and Model 4 outperformed the random walk, whereas Model 2 correctly predicted the direction of change significantly more than half the time in emerging markets.

Table 11. *Panel Fit Statistics*

		Original Data					Demeaned Data		
ALL	Model1	Model2	Model3	Model4	ALL	Model1	Model2	Model3	Model4
RMSE	0.0546	1.2917	0.0548	0.0551	RMSE	0.0383	1.2864	0.0370	0.1048
THEIL	1.0000	23.6419	1.0025	1.0091	THEIL	1.0000	33.6077	**0.9668**	2.7377
DOC	0.4444	0.4876	0.4629	0.4866	DOC	0.4720	0.4962	0.4887	0.4855
PVAL	0.0006*	0.4513	0.0237*	0.4129	PVAL	0.0847	0.8187	0.4916	0.3765
DEV	Model1	Model2	Model3	Model4	DEV	Model1	Model2	Model3	Model4
RMSE	0.0459	1.1243	0.0490	0.0484	RMSE	0.0316	1.1221	0.0312	0.1089
THEIL	1.0000	24.4892	1.0671	1.0540	THEIL	1.0000	35.4951	**0.9872**	3.4433
DOC	0.4190	**0.5157**	0.4217	0.4578	DOC	0.4810	**0.5205**	0.4771	**0.5084**
PVAL	0.0009*	0.5240	0.0014*	0.0858	PVAL	0.4356	0.4047	0.3516	0.7316
EMR	Model1	Model2	Model3	Model4	EMR	Model1	Model2	Model3	Model4
RMSE	0.0607	1.0576	0.0591	0.0600	RMSE	0.0429	1.0540	0.0416	0.1012
THEIL	1.0000	17.4352	**0.9738**	**0.9895**	THEIL	1.0000	24.5916	**0.9701**	2.3620
DOC	0.4648	**0.6066**	0.4942	**0.5097**	DOC	0.4648	**0.5504**	0.4864	0.4671
PVAL	0.1064	0.0000*	0.7920	0.6602	PVAL	0.1064	0.0219*	0.5382	0.1346

*
significant at the 5% level
DOC ratios > 0.50 are in bold, while the box indicates significantly > 0.50.

For the combined demeaned data, only Model 3 outperformed the random walk in terms of the Theil ratio, whereas none of the models correctly predicted the direction of change more than half the time. When the combined demeaned data were grouped into developed and emerging markets, only Model 3 outperformed the random walk, whereas none of the models correctly predicted the direction of change significantly more than half the time. Model 3 also outperformed the random walk in emerging markets, whereas only Model 2 correctly predicted the direction of change significantly more than half the time.

The panel fit statistics provide some evidence of the outperformance of Model 3 in terms of the Theil ratio, but not by much. The instances when Model 3 outperformed the random walk all had Theil ratios higher than 0.96, indicating that their RMSEs are not very far from those of the benchmark. The panel fit statistics also provide some evidence that Model 2 can predict the direction of change for emerging markets significantly more than half the time, but only in 60% of cases for raw data and 55% of cases for demeaned data.

Conclusion

This study finds evidence for a relationship between money supply and real output on the one hand and exchange rates on the other, as predicted by economic theory. It also finds evidence that foreign exchange rates of emerging markets are more predictable in terms of this relationship compared to those of developed markets. Although the results of single-country analyses were inconclusive, the panel regression, panel cointegration, and panel fit tests all indicate that money supply and real output are determinants of the exchange rate. Finally, this study finds some evidence that Model 2 can predict the direction of change significantly more than half the time, but not by much and only for emerging markets.

Overall, these findings align with the results of Groen (2000), Mark and Sul (2001), Rapach and Wohar (2002), Groen (2005), Engel et al. (2008), and Cerra and Saxena (2010), as they all found evidence supporting a relationship between economic fundamentals and exchange rates. These authors observed cointegration between monetary variables and exchange rates, suggesting a long-run relationship and significant predictive power of monetary models for future exchange rate movements. Moreover, the findings regarding the predictability of exchange rates in emerging markets compared to developed markets are in line with Cerra and Saxena (2010), who found that monetary models were more effective in predicting exchange rates in emerging markets. Conversely, the results contradict those of Meese and Rogoff (1983), Kilian (1999), and Faust et al. (2003), who did not find convincing evidence supporting the relationship between economic fundamentals and exchange rates or the predictive power of economic models over random walk models.

The findings of this study hold important implications for policymakers, enabling central banks to refine their monetary policy tools for managing exchange rates and capital flows, particularly in emerging markets. Moreover, economic planners can incorporate insights from foreign exchange movements to formulate strategic economic plans effectively. Beyond policymakers, businesses ranging from exporters and importers to financial institutions stand to benefit, as an improved understanding of foreign exchange dynamics facilitates better decision-making in areas such as inventory management, risk mitigation, and pricing strategies. Particularly in emerging markets where bilateral trade has surged in recent years, this research provides valuable insights for businesses of all scales, helping them navigate the complexities of global exchange rate fluctuations and government policies.

The limitation of this study is that data was limited to those available in the IFS database and to a period of less than 20 years (2001Q4 to 2020Q2), which may have rendered the single-country regression models and cointegration tests inconclusive. This was partially alleviated by using panel methods of analyses, which were able to find significant results in panel regression models and panel cointegration tests. The limited data also restricted the out-of-sample analysis to a one-year horizon. A natural extension of this study would be to examine more countries for more periods of time to increase the power and significance of the tests as well as to extend the out-of-sample analysis to longer time periods. This research may also be extended by making use of alternative models, tests, and methods to analyze the data, such as quantile-based forecasting.

An interesting extension would be to investigate the reasons for the differences in results among the various studies of exchange rate predictability over the past 50 years. The findings of this study on the exchange rate predictability contrast with earlier studies that did not find any relationship but are in line with more recent ones that did. What accounts for the differences? Whether or not a study finds a relationship may depend on when the study was done. Earlier studies, those prior to 1993, did not find any relationship, while more recent ones, undertaken 1993 onwards, did. One possibility is the occurrence of a structural change in the foreign exchange market. As markets around the world liberalized, more and more currencies floated and behaved more in accordance with the flexible price monetary model, which assumes a free market. A second related possibility is the integration of European currencies into the Euro, which eliminated several "Euro legacy" currencies that were correlated and moved in tandem. This would have a profound effect on this study as it is the first to focus on post Euro period and exclude the Euro legacy currencies. This study can thus be extended to confirm the structural break caused by the introduction of the Euro, and if it changed the relationships and dynamics among economic variables and exchange rates. It can also be extended to examine country-specific characteristics and factors that determine these relationships.

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