Received: 28 September 2020 | Revised: 13 January 2021 | Accepted: 18 May 2021

DOI: 10.1002/for.2795

RESEARCH ARTICLE

WILEY

Stock markets and exchange rate behavior of the BRICS

Afees A. Salisu[1] | Juncal Cuñado[2] | Kazeem Isah[1] | Rangan Gupta[3]

[1]Centre for Econometric and Allied Research, University of Ibadan, Ibadan, Nigeria

[2]Economics Department, University of Navarra, Pamplona, Spain

[3]Economics Department, University of Pretoria, Pretoria, South Africa

Correspondence
Juncal Cuñado, Economics Department, University of Navarra, Pamplona, Spain.
Email: jcunado@unav.es

Funding information
Ministerio de Economía y Competitividad, Spain, Grant/Award Number: ECO2017-83183-R

Abstract

Relying on the uncovered equity parity (UEP), we formulate a predictive model that links movements in exchange rate to stock return differential between the domestic market and the foreign (US) market. We also test for any probable asymmetric relationship between the two variables while also accounting for the role of observed common (global) factor such as oil price. We find a positive relationship between stock return differential and exchange rate return for three of the BRICS countries namely Brazil, India and South Africa, thus validating the UEP hypothesis, whereas a contrasting evidence is observed for China and Russia. We further establish the out-of-sample predictability of stock return differential for exchange rates of the BRICS while accounting for the role of observed common (global) factor, and asymmetry may further improve the forecast accuracy. The implications of our findings for portfolio diversification and foreign exchange management are highlighted.

KEYWORDS

exchange rate, forecast evaluation, stock market, uncovered equity parity

1 | INTRODUCTION

Since the seminal paper by Meese and Rogoff (1983a, 1983b) showing that exchange rate forecasting models were unlikely to outperform the random walk prediction, many attempts have been made to predict movements in exchange rate (Abhyankar et al., 2005; Bacchetta et al., 2010; Berkowitz & Giorgianni, 2001; Kilian & Taylor, 2003; Rossi, 2013). As an example, according to the uncovered equity parity (UEP), when foreign equity holdings outperform domestic holdings, domestic investors are exposed to higher exchange rate risk and hence rebalance their portfolio repatriating some of the foreign equity to decrease their exchange rate risk. By doing so, foreign currency is sold, leading to foreign currency depreciation (Cappiello & De Santis, 2005, 2007; Chen & Hsu, 2019; Curcuru et al., 2014; Hau & Rey, 2006), suggesting that a strong (weak) stock market precedes a weak (strong) currency.

Although the empirical literature supports, in general,[1] the UEP hypothesis in advanced and developed economies (Cappiello & De Santis, 2007; Chen & Hsu, 2019; Curcuru et al., 2014; Gelman et al., 2015; Hau & Rey, 2006; Kim, 2011; Melvin & Prins, 2015), the results are scarce and not conclusive for developing countries (Aftab et al., 2018; Baur & Miyakawa, 2013; Kim, 2011). For example, for developed countries, Hau and Rey (2006) find strong support when testing the hypothesis for 17 OECD countries and conclude that the exchange rate dynamics are related to equity market development. Similar results are reported by Curcuru et al. (2014) when they analyze the US economy. However, Baur and Miyakawa (2013) find empirical support for the UEP hypothesis for only a relatively small number of currencies, such as the US dollar, the UK pound, the Swiss franc, or the Japanese yen, when they analyze the behavior of 53 currencies. Also, the evidence reported by Aftab et al. (2018) for six East Asian emerging markets

(Indonesia, Korea, Malaysia, The Philippines, Thailand, and Singapore) runs contrary to the UEP hypothesis.

In this context, the objective of this paper is to analyze the ability of stock return differentials to predict movements in exchange rate of the BRICS countries and, thus, to test whether the UEP hypothesis holds for these countries. This paper contributes to the literature on exchange rates predictability in several ways. First, unlike most of the literature, we examine the predictability of stock return differentials for exchange rates in a sample of emerging countries by focusing on the BRICS (Brazil, Russia, India, China, and South Africa) countries. These emerging countries[2] have played an increasingly important role in the world economy in the last two decades, and investors, looking for return differentials and diversification opportunities, have shifted their interest to these countries. In fact, the BRICS nations not only represent 42% of the total global population and 23% of total global gross domestic product (GDP) (International Monetary Fund [IMF], 2019) but also attracted 20% of the world foreign direct investment (FDI) inflows and received 17% of the FDI outflows in 2018 (UNCTAD, 2019). Moreover, the excess returns of emerging markets have been higher than in developed markets during the last decades, and emerging market stock returns have also had a low correlation with developed market returns, providing international investors with favorable risk and return tradeoffs and risk diversification opportunities. Furthermore, and according to the predictions in a 2010 report from Goldman Sachs, China could surpass the USA in equity market capitalization terms by 2030 and become the single largest equity market in the world (Moe et al., 2010), while by that year, the four BRICs would account for 41% of the world's market capitalization. Unlike exchange rates in developed economies, BRICS countries' exchange rates have not been allowed to float freely, but they have been strictly controlled by different currency policies (Jiang, 2019) until recently, so that exchange rates in these countries could respond differently to the investment flows. For example, China fixed its exchange rate in 1995 to the US dollar and maintained that peg until July 2005, while the ruble has been trading freely since 2014, when Russia abandoned a previous peg. Moreover, the exchange rate system in India has transited from a fixed exchange rate regime to the present form of freely determined exchange rate regime since 1993, while Brazil and South Africa adopted a floating exchange rate regime in 1999 and 2000, respectively. Analyzing to what extent and in which direction stock return differentials may drive movements in exchange rate will be of interest for foreign investors, and for the design of exchange rate policies in those countries where governments can intervene to manage the value of the exchange rate. That is, it would be interesting to test whether strong stock markets will lead to strong or weak currencies for these emerging economies. Because each of the BRICS countries has chosen different exchange rate regimes or currency interventions, the response of exchange rates to stock return differentials could be different in each of the countries.

The second contribution relates to the evidence of out-of-sample forecasting of exchange rate movements in the literature. Most of the studies involving out-of-sample exchange rate forecasting conclude that it would be difficult for any theory-based model to beat the benchmark model, whether historical average or random walk (see, e.g., Ferraro et al., 2015; Moosa, 2013; Moosa & Burns, 2014a, 2014b, 2014c; Rossi, 2013). We however argue and demonstrate that the overarching evidence in the literature may be upturned using an alternative theoretical model, which relies on the unequal equity parity hypothesis (details of which are provided in the Section 3) where the predictive contents of stock return differential for exchange rate movements are analyzed. Up to our knowledge, Chen and Hsu (2019) is the only paper that analyzes out-of-sample forecast ability of stock return differentials for movements in exchange rate, although their analysis includes the seven most-traded currencies (the US dollar, euro, Japanese yen, British pound, Australian dollar, Swiss franc, and Canadian dollar), whereas our paper focuses on the currencies of the BRICS nations. Third, this paper contemplates the possibility of asymmetric responses of exchange rates to oil prices, allowing that exchange rates might react differently to positive and negative stock return differentials (Aftab et al., 2018). Fourth, and based on the relevance of BRICS countries in the generation and consumption of energy,[3] we also control for a common global factor, oil prices,[4] when testing the predictability of stock return differential for exchange rates. Finally, and for robustness purposes, we replicate the analysis for the UK economy in order to draw inferences from a developed market perspective.

The main results show a positive relationship between stock return differential and exchange rate return, and thus, they support the UEP hypothesis, for Brazil, India, and South Africa, while a contrasting result for China and Russia. Moreover, for all the BRICS countries, the in-sample and out-of-sample forecast performance suggests that stock return differential is a good predictor of exchange rate, while accounting for the role of observed common factor (oil prices) and asymmetry improves the exchange rate predictability. Finally, the main results of the paper for the BRICS countries are consistent with those obtained for a developed economy such as the UK.

Following the introduction, we describe the data and render some preliminary analyses in Section 2; we present the model and estimation procedure in Section 3; the empirical results are presented and discussed in Section 4 while Section 5 contains some concluding remarks.

2 | DATA AND PRELIMINARY ANALYSES

To achieve the study objective, we utilize historical monthly data for both exchange rate and stock returns of the BRICS countries. The predicted series (i.e., exchange rate measured as the cost of domestic currency to US $1) is expressed in log return form for the purpose of empirical analysis while the predictor series (i.e., stock return differential) is computed as the difference between stock log returns of the domestic stock market and that of the foreign stock market.[5] However, while both exchange rate and stock data are obtained from Global Financial Data,[6] the start date varies across countries due to data availability. For instance, the start date for Brazil is January 1954, while it is December 1994 and July 1920 for Russia and India, respectively. For China and South Africa, the start date is December 1992 for the former and January 1910 for the latter. Nonetheless, all the countries have a uniform end date, which is June 2020.

As customary for empirical analysis, we render some descriptive statistics for the relevant series. In Table 1, we present the mean and standard deviation statistics for exchange rate return and stock return differential. Essentially, we find that Brazil has the highest level of depreciation over the period under consideration followed by the Russian rubble, while the Chinese Yuan appears to be the strongest and equally doubles as the currency with the least standard deviation value. In other words, Yuan enjoys a relatively stable exchange rate, on the average, over the period under study. On the predictor series, we find that the mean values for stock return differential are positive for Brazil, Russia, and South Africa whereas they are negative for India and China. These statistics seem to suggest that the larger the values of the stock return differential, the larger the depreciation of the domestic currency relative to the reference currency. In Panel B, we offer some unit root tests, a requirement for time series analysis. We consider both the augmented Dickey-Fuller (ADF) test and the GARCH-based unit root test of Narayan and Liu (2015) for robustness. The results consistently reject the null hypothesis of unit root for the relevant series regardless of the choice of unit root test.

TABLE 1 Preliminary results

	Exchange rate return		Stock return diff.		Obs.
Panel A: descriptive statistics					
	Mean	**Std. dev.**	**Mean**	**Std. dev.**	
Brazil	4.21	8.66	4.84	20.18	797
Russia	0.98	5.70	1.05	9.92	306
India	0.28	2.50	−0.05	5.90	1,199
China	0.06	2.31	−0.63	8.33	330
S-Africa	0.28	2.89	0.18	5.17	1,325

Panel B: unit root test				
	Exchange rate return		**Stock return diff.**	
	ADF	**NL (2015)**	**ADF**	**NL (2015)**
Brazil	−6.95***	−0.35***	19.09**	−0.61***
Russia	−12.68***	−0.51***	−14.22***	−0.81***
India	−32.31***	−1.01***	−27.10***	−0.79***
China	−17.47***	−1.00**	−15.33***	−0.85***
S-Africa	−29.14***	−0.75***	−29.64***	−0.80***

Note: Std. dev. in "Panel A" denotes standard deviation; "Obs." is for observations and "diff." as used in Stock return diff. denotes differential; ADF denotes augmented Dickey–Fuller; NL (2015) is for Narayan and Liu (2015) GARCH-based unit root test.
***1%.
**5%.
*10%.

In the next section, we formulate a predictive model that accommodates the outcome of the unit root test results.

3 | METHODOLOGY

This study relies on the UEP for the predictability analysis between stock return differential and exchange rate. The underlying intuition is that, when foreign equity holdings outperform their domestic counterparts, domestic investors are exposed to higher exchange rate and hence repatriate some of the foreign equity to decrease their exchange rate risk (Curcuru et al., 2014). This rebalancing usually results in the selling of foreign currency thus leading to foreign currency depreciation. In the context of UEP, a positive association is hypothesized between stock return differentials and exchange rate because a weak currency is associated with a strong equity market due to portfolio rebalancing (Chen & Hsu, 2019). Some empirical studies have offered evidence in support of the UEP (i.e., positive correlation between the two variables in question) (see Cappiello & De Santis, 2005, 2007; Chen & Hsu, 2019; Curcuru et al., 2014; Gelman et al., 2015; Hau & Rey, 2006; Kim, 2011) while there is also evidence of a negative correlation (see Bohn & Tesar, 1996; Cenedese et al., 2016; Chabot et al., 2014; Chen & Hsu, 2019; Griffin et al., 2004; Malliaropulos, 2008; Ülkü et al., 2016; Wong & Li, 2013). In other words, the relationship can run either way.[7] We construct a predictive model that links exchange rate to stock return differential in line with the UEP[8]:

$$e_t = \alpha + \beta\left(r_t^d - r_t^f\right) + \varepsilon_t \tag{1}$$

where e_t is the exchange rate return computed as log difference of nominal exchange rate (s_t) in month t, and US dollar (USD) is the reference (foreign) currency. Hence, an increase in s_t implies a depreciation of the domestic currency relative to USD whereas a decrease in s_t implies otherwise. The predictor $\left(r_t^d - r_t^f\right)$ is the stock return differential, which measures the difference in the stock returns of domestic and foreign stock markets where the latter is the US stock market being the reference currency for e_t. Note that r_t^d is the domestic stock return series while r_t^f represents the foreign stock returns and both are computed as first difference of log of stock price index. We test the null hypothesis of no predictability $\beta = 0$ against the alternative hypothesis of predictability $\beta \neq 0$. As noted in the previous section on preliminary analysis and given the way the variables are captured in the model, we do not suspect any unit root problem; thus, the t test statistic obtained from the ordinary least squares estimator is assumed relatively unbiased and efficient and should suffice for the predictability analysis.[9]

One of the limitations of Equation 1 is that it assumes that positive and negative values of $\left(r_t^d - r_t^f\right)$ will have identical effect on exchange rate. However, exchange rates are found to respond asymmetrically to macro fundamentals (although not from the perspective of stock return differential) (see Ferraro et al., 2015; Salisu et al., 2019). Consequently, we construct a model where the response of exchange rate to positive and negative stock differential is distinctly evaluated:

$$e_t = \alpha + \beta\left(r_t^d - r_t^f\right) + \gamma D_t + \lambda D_t * \left(r_t^d - r_t^f\right) + \varepsilon_t \tag{2}$$

where $D = 1$ if $\left(r_t^d - r_t^f\right) > 0$ and zero otherwise. As a consequence, β measures negative asymmetry (i.e., effect of negative stock differential on exchange rate) while positive asymmetry is measured as $\beta + \lambda$ with the joint significance determined using the Wald test. The presence of asymmetry or otherwise is evaluated with λ, which can also be referred to as differential slope coefficient used to determine if the difference in the negative and positive asymmetry coefficients is statistically significant. The parameter γ is the differential intercept coefficient and it is used to determine if the average exchange rate return differs between positive and negative changes in stock differential. For robustness, we also account for a global factor, oil price, in the model (see Chen & Hsu, 2019; Ferraro et al., 2015; Salisu et al., 2019; Salisu et al., 2020) and thus, we are able to evaluate the sensitivity of the relationship between stock differential and exchange rate to control variables.

Finally, we evaluate the out-of-sample predictability of stock differential for exchange rate using the h-ahead forecast model specified as

$$e_{t+h} = \alpha + \beta\left(r_t^d - r_t^f\right) + \varepsilon_{t+h} \tag{3}$$

where h denotes 1, 3, 6, 12, and 24 out-of-sample forecast horizons while other variables and parameters are as previously defined. We use a 75:25 data split respectively for the in-sample and out-of-sample forecast analysis while the rolling window approach is used to obtain the forecasts. We render the forecast evaluation of the predictor using Campbell and Thompson (2008) and Clark and West (2007) tests.[10] The Campbell and Thompson (2008) test statistic is computed as $1 - \left(M\hat{S}E_u / M\hat{S}E_r\right)$ where $M\hat{S}E_u$ is the mean squared error obtained from the stock-based model (which is technically an unrestricted model in this case) and $M\hat{S}E_r$ is the mean squared error obtained from the model which ignores the role of stock differential (using both the historical average model and the random walk model without drift[11] in this paper). The terms $M\hat{S}E_r$ and $M\hat{S}E_u$ are respectively computed as $N^{-1}\sum(e_{t+h}-\hat{e}_{r,t+h})^2$ and $N^{-1}\sum(e_{t+h}-\hat{e}_{u,t+h})^2$ where N is the forecast simple; e and $\hat{e}$ are the actual and fitted exchange rates respectively; while the subscripts "r" and "ur" are respectively for the restricted and unrestricted models. In terms of interpretation, the unrestricted model offers better forecasts if the test statistic is positive; otherwise, the restricted model is preferred. The Clark and West (2007) test is a complementary test for the Campbell and Thompson (2008) test as it allows us to determine whether the difference in the errors of two nested competing models is statistically significant or not. The test involves four steps: (i) estimate the two competing models and compute their corresponding mean square errors (i.e., $M\hat{S}E_r$ and $M\hat{S}E_u$); (ii) adjust the $M\hat{S}E_u$ (symbolized as for adj) for any inherent noise by using the formula $N^{-1}\sum(\hat{e}_{r,t+h}-\hat{e}_{u,t+h})^2$; (iii) compute the forecast error difference $\left(\hat{f}_{t+h}\right)$ using the formula $M\hat{S}E_r-\left(M\hat{S}E_u-adj\right)$; (iv) regress the $\hat{f}_{t+h}$ on a constant and report the corresponding t-statistic. It is a one-sided test, and the null hypothesis of a zero coefficient is rejected if this statistic is greater than the critical value for any of the conventional levels where it is +1.282, +1.645 and +2.00 for 10%, 5%, and 1%, respectively (Clark & West, 2007).

4 | DISCUSSION OF RESULTS

4.1 | In-sample predictability

Table 2 illustrates the predictability test of stock return differential for exchange rate of the BRICS. Confirming the UEP hypothesis, we find a positive relationship between stock return differential and exchange rate return of three of the BRICS countries namely, Brazil, India, and South Africa. This implies that an increase in stock return differential will cause the domestic currency to depreciate relative to the foreign currency. As the domestic stock market offers higher expected returns, a domestic investor suffers a loss when investing abroad and therefore should be compensated by the expected capital gain that occurs when the foreign currency appreciates (Chen & Hsu, 2019). However, beyond the fact that the coefficient on Russian exchange rate is not statistically significant (although, correctly signed), the predictability results for the Chinese yuan tend to contradict the UEP prediction, but the results yet find support in Griffin et al. (2004); Hau and Rey (2006); Malliaropulos, 2008; Wong and Li (2013); Chabot et al. (2014), Ülkü et al. (2016), and Chen and Hsu (2019). This contrasting evidence to the UEP hypothesis can be attributed to return chasing behavior of investors, whereby investors decide to increase their holdings in market that have recently outperformed other markets. Thus, the domestic currency of China is likely to appreciate when the domestic stock market outperforms the US market.

When we control for the role of changes in oil price in the nexus, measured as log of the first difference of the monthly spot oil price using the West Texas Intermediate (WTI) crude oil as a proxy, we find little or no difference in the direction of the nexus. That is, except for the magnitude of the impact of the nexus, where the coefficients on exchange rate return appear to be relatively higher for India, China, South Africa, and even Russia in the model with control, the significance as well as the direction of the relationship remains the same for both models (with and without control). On whether accounting for "asymmetry" effect matters in the nexus, we find the null

TABLE 2 Predictability results

	Brazil	Russia	India	China	South Africa
Without control	0.1315*** (0.0145)	0.0038 (0.0329)	0.0340*** (0.0121)	−0.0297** (0.0152)	0.0309** (0.0135)
With control	0.1311*** (0.0144)	0.0172 (0.0325)	0.0352*** (0.0121)	−0.0301** (0.0152)	0.0350** (0.0152)
With asymmetry					
Positive asymmetry	0.1783*** (0.0160)	0.0926 (0.0572)	0.0731*** (0.0243)	0.0016 (0.0295)	0.0384 (0.0297)
Negative asymmetry	−0.3375*** (0.0613)	−0.1313** (0.0654)	0.0067 (0.0236)	−0.0749** (0.0316)	−0.0311 (0.0332)
Asymmetry test	0.5158*** (0.0634)	0.2240** (0.0869)	0.0664** (0.0339)	0.0765* (0.0433)	0.0696 (0.0446)

Note: "Without control" implies the original model with the predictor of stock return differential only, while "With control" is an extension of the original model to include relevant control variables (i.e., oil price). "With asymmetry" implies the model with distinct coefficients for positive stock return differential and negative stock return differential, while asymmetry test is the Wald test for coefficient restriction used to test whether exchange rate responds differently to positive and negative stock return differentials. Standard errors of the coefficients are in parentheses.

***1%.

**5%.

*10%.

hypothesis of no asymmetry consistently rejected for all the BRICS countries with the exception of South Africa. This indicates that exchange rate responds differently to positive and negative stock return differential of the same magnitude. More specifically, exchange rates of the BRICS tend to respond more to negative stock return differential (where the foreign [US] stock market outperforms the domestic stock market) than the positive stock return differential (where the domestic stock market outperforms the foreign stock market). On the whole, we find support for the UEP hypothesis in a number of the BRICS countries. More importantly, we

TABLE 3 Root mean square error (RMSE)-based forecast performance results

	Model 1				
Forecast horizon	**Brazil**	**Russia**	**India**	**China**	**South Africa**
In-sample	8.9518	5.9106	2.6931	2.5711	2.6240
h = 1	8.9500	5.9041	2.6916	2.5660	2.6227
h = 3	8.9384	5.8820	2.6942	2.5560	2.6209
h = 6	8.9208	5.8500	2.6925	2.5429	2.6175
h = 12	8.9081	5.9879	2.6936	2.5145	2.6128
h = 24	8.8727	6.0640	2.6770	2.4643	2.6014
Model 2					
In-sample	8.9467	5.9043	2.6926	2.5710	2.6240
h = 1	8.9445	5.8984	2.6911	2.5659	2.6227
h = 3	8.9326	5.8764	2.6938	2.5559	2.6209
h = 6	8.9156	5.8443	2.6920	2.5427	2.6175
h = 12	8.9024	5.9616	2.6928	2.5143	2.6128
h = 24	8.8667	6.0246	2.6763	2.4645	2.6014
Model 3					
In-sample	8.6490	5.8375	2.6885	2.5568	2.6226
h = 1	8.6469	6.0191	2.6870	2.5517	2.6213
h = 3	8.6353	5.8350	2.6898	2.5416	2.6195
h = 6	8.6152	5.8115	2.6880	2.5289	2.6162
h = 12	8.5974	5.7784	2.6889	2.5009	2.6115
h = 24	8.5571	5.9396	2.6725	2.5417	2.6001
Model 4					
In-sample	9.4046	5.9108	2.7178	2.5857	2.6262
h = 1	9.4025	5.9044	2.7164	2.5806	2.6249
h = 3	9.3912	5.8823	2.7185	2.5705	2.6232
h = 6	9.3725	5.8503	2.7168	2.5573	2.6198
h = 12	9.3593	5.9884	2.7180	2.5289	2.5161
h = 24	9.3260	6.0638	2.7008	2.4775	2.6038
Model 5					
In-sample	10.9051	5.9235	2.7205	2.5908	2.6351
h = 1	10.8965	5.9203	2.7190	2.5857	2.6339
h = 3	10.8790	5.8983	2.7218	2.5754	2.6324
h = 6	10.8552	5.8629	2.7606	2.5622	2.6291
h = 12	10.8046	6.0381	2.7217	2.5337	2.6247
h = 24	10.7080	6.1206	2.7045	2.4820	2.6136

Note: Model 1 is the model without control; Model 2 is the model with control; Model 3 is the model with asymmetry; Model 4 is the historical average model and Model 5 is the random walk model without drift. For the RMSE measure, lower values are preferred.

find that the results are robust (i.e., insensitive) to exogenous conditions such as changes in oil price while accounting for whether asymmetry matters in the nexus.

4.2 | Forecast performance results

We further examine the in-sample and out-of-sample forecasting prowess of stock return differential for movements in exchange rate. As noted previously, we use both the single (root mean square error [RMSE]) and pairwise (Campbell & Thompson, 2008 [C–T hereafter] and Clark & West, 2007 [C–W hereafter]) forecast measures for the forecast evaluation exercise. We present in Table 3, the in-sample and out-of-sample forecast performance results using the RMSE measure. We consider out-of-sample forecast horizons of 1, 3, 6, 12, and 24 months. But the dominant position in the literature is that future exchange rates are difficult to forecast (see Moosa, 2013; Moosa & Burns, 2012, 2014a, 2014b, 2014c), we however find lower values of the RMSE for Models 1, 2, and 3 compared with those obtained from the historical average of the exchange return (Model 4) and the driftless random walk model (Model 5) both of which are the benchmark models adopted in this study. We also find that RMSE values tend to reduce after controlling for oil price changes and accounting for asymmetry effect in stock return differential. This outcome remains the same for both the in-sample and out-of-sample predictability.

We also complement the RMSE-based forecasts with the pairwise measures, and the results are presented in Tables 4–7 for C–T and C–W tests, respectively where Tables 4 and 5 involve the historical average model as the benchmark model while Tables 5 and 7 present results relative to the driftless random walk. A positive value of the C–T test implies the outperformance of the unrestricted model over the restricted model while a negative value of the test implies otherwise. As shown in Tables 4 and 5, the C–T statistics are positive for all the variants of the stock-based model over the countries under consideration. Thus, any predictive model of

TABLE 4 Forecast evaluation using the Campbell and Thompson (2008) test where historical average is the benchmark model

	Model 4 vs. Model 1				
Forecast horizon	**Brazil**	**Russia**	**India**	**China**	**South Africa**
In-sample	0.0482	3.66E-05	0.0091	0.0056	0.0009
h = 1	0.0481	3.96E-05	0.0092	0.0057	0.0009
h = 3	0.0482	5.48E-05	0.0089	0.0056	0.0009
h = 6	0.0481	5.92E-05	0.0089	0.0056	0.0009
h = 12	0.0481	7.23E-05	0.0090	0.0057	0.0009
h = 24	0.0486	−2.85E-05	0.0088	0.0053	0.0008
Model 4 vs. Model 2					
In-sample	0.0486	0.0011	0.0092	0.0056	0.0009
h = 1	0.0487	0.0010	0.0093	0.0057	0.0009
h = 3	0.0488	0.0010	0.0091	0.0057	0.0009
h = 6	0.0487	0.0010	0.0091	0.0057	0.0009
h = 12	0.0488	0.0044	0.0092	0.0058	0.0009
h = 24	0.0492	0.0064	0.0091	0.0052	0.0008
Model 4 vs. Model 3					
In-sample	0.0803	0.0124	0.0107	0.0111	0.0014
h = 1	0.0804	0.0117	0.0108	0.0112	0.0014
h = 3	0.0805	0.0120	0.0106	0.0112	0.0014
h = 6	0.0807	0.0123	0.0106	0.0111	0.0013
h = 12	0.0814	0.0081	0.0107	0.0111	0.0014
h = 24	0.0824	0.0073	0.0104	0.0104	0.0014

Note: Model 1 is the model without control; Model 2 is the model with control; Model 3 is the model with asymmetry; Model 4 is the historical average model. For the Campbell and Thompson (2008) test, positive values imply superior performance of the unrestricted model over the restricted model whereas negative values imply otherwise.

TABLE 5 Forecast evaluation using the Campbell and Thompson (2008) test where random walk model without drift is the benchmark model

Forecast horizon	Model 5 vs. Model 1 Brazil	Russia	India	China	South Africa
In-sample	0.1791	0.0021	0.0100	0.0076	0.0042
h = 1	0.1786	0.0027	0.0100	0.0075	0.0042
h = 3	0.1783	0.0027	0.0101	0.0075	0.0043
h = 6	0.1787	0.0022	0.0103	0.0075	0.0044
h = 12	0.1755	0.0083	0.0103	0.0075	0.0045
h = 24	0.1713	0.0092	0.0101	0.0071	0.0046
Model 5 vs. Model 2					
In-sample	0.1795	0.0032	0.0102	0.0076	0.0042
h = 1	0.1791	0.0036	0.0102	0.0076	0.0042
h = 3	0.1789	0.0037	0.0102	0.0075	0.0043
h = 6	0.1786	0.0031	0.0104	0.0075	0.0044
h = 12	0.1760	0.0126	0.0106	0.0076	0.0045
h = 24	0.1719	0.0156	0.0104	0.0070	0.0046
Model 5 vs. Model 3					
In-sample	0.0047	0.0145	0.0117	0.0131	0.0047
h = 1	0.0047	0.0144	0.0117	0.0131	0.0047
h = 3	0.0049	0.0147	0.0117	0.0131	0.0049
h = 6	0.0049	0.0144	0.0119	0.0129	0.0049
h = 12	0.0050	0.0163	0.0120	0.0129	0.0050
h = 24	0.0051	0.0165	0.0118	0.0122	0.0051

Note: Model 1 is the model without control; Model 2 is the model with control; Model 3 is the model with asymmetry; Model 5 is the random walk model without drift. For the Campbell and Thompson (2008) test, positive values imply superior performance of the unrestricted model over the restricted model whereas negative values imply otherwise.

TABLE 6 Forecast evaluation using the Clark and West (2007) test where historical average is the benchmark model

Forecast horizon	Model 4 vs. Model 1 Brazil	Russia	India	China	South Africa
In-sample	16.6254*** [3.9613]	0.0051 [0.1176]	0.2683*** [3.1265]	0.1509 [0.0102]	0.0237 [1.0042]
h = 1	16.6029*** [3.9625]	0.0053 [0.1225]	0.2681*** [3.1281]	0.1502 [1.0096]	0.0237 [1.0064]
h = 3	16.5755*** [3.9699]	0.0063 [0.1476]	0.2653*** [3.1008]	0.1488 [1.0081]	0.0240 [1.0203]
h = 6	16.5076*** [3.9724]	0.0065 [0.1547]	0.2658*** [3.1164]	0.1474 [1.0110]	0.0237 [1.0104]
h = 12	16.4115*** [3.9881]	0.0076 [0.1839]	0.2663*** [3.1418]	0.1454 [1.0203]	0.0235 [1.0069]
h = 24	16.2731*** [4.0316]	0.0002 [0.0065]	0.2628*** [3.1406]	0.1399 [1.0261]	0.0238 [1.0302]
Model 4 vs. Model 2					
In-sample	16.8071*** [4.0237]	0.1546 [0.5870]	0.2731*** [3.2541]	0.1519 [0.9983]	0.0237 [1.0015]
h = 1	16.7927*** [4.0269]	0.1470 [0.5604]	0.2729*** [3.2253]	0.1513 [0.9980]	0.0237 [1.0037]
h = 3	16.7707*** [4.0350]	0.1464 [0.5613]	0.2699*** [3.2256]	0.1499 [0.9966]	0.0240 [1.0176]
h = 6	16.6951*** [4.0366]	0.1457 [0.5674]	0.2707*** [3.2446]	0.1486 [1.0000]	0.0237 [1.0178]
h = 12	16.6067*** [4.0548]	0.4011 [1.3801]	0.2730*** [3.2911]	0.1467 [1.0103]	0.0235 [1.0036]
h = 24	16.4763*** [4.1047]	0.5590** [1.9266]	0.2691*** [3.2869]	0.1396 [1.0053]	0.0238 [1.0286]

TABLE 6 (Continued)

Forecast horizon	Model 4 vs. Model 1 Brazil	Russia	India	China	South Africa
Model 4 vs. Model 3					
In-sample	27.2855*** [5.3901]	1.7231*** [3.0595]	0.3170*** [2.8064]	0.2971 [1.0240]	0.0384 [1.2279]
h = 1	27.2593*** [5.3811]	1.6767*** [2.9800]	0.3168*** [2.8080]	0.2965 [1.0260]	0.0384 [1.2298]
h = 3	27.2063*** [5.3634]	1.6879*** [3.0257]	0.3133*** [2.7824]	0.2950 [1.0290]	0.0386 [1.2396]
h = 6	27.1420*** [5.3371]	1.6890*** [3.0666]	0.3137*** [2.7946]	0.2900 [1.0237]	0.0380 [1.2231]
h = 12	27.1167*** [5.1304]	1.4231** [2.5793]	0.3152*** [2.8248]	0.2844 [1.0274]	0.0377 [1.2224]
h = 24	26.9773 [5.2034]	1.3619** [2.5227]	0.3103*** [2.8178]	0.2720 [1.0278]	0.0382 [1.2499]

Note: Model 1 is the model without control; Model 2 is the model with control; Model 3 is the model with asymmetry; Model 4 is the historical average model. The Clark and West (2007) test is a one-sided test, and the null hypothesis of a zero coefficient (implying equality in forecast accuracy of two competing models) is rejected if this statistic is greater than the critical value for any of the conventional levels where it is +1.282, +1.645, and +2.00 for 10%, 5%, and 1% levels, respectively (Clark & West, 2007). Values in square brackets [] are for *t*-statistics.
***1% level.
**5% level.
*10% level.

TABLE 7 Forecast evaluation using the Clark and West (2007) test where random walk model without drift is the benchmark model

Forecast horizon	Model 5 vs. Model 1 Brazil	Russia	India	China	South Africa
In-sample	77.3049*** [9.8639]	1.4955*** [2.0268]	0.4064*** [3.5327]	0.1525 [0.9723]	0.1039*** [2.2677]
h = 1	77.1316*** [9.8558]	1.5333*** [2.0843]	0.4059*** [3.5326]	0.1517 [0.9715]	0.1041*** [2.2748]
h = 3	76.8946*** [9.8560]	1.5321*** [2.0996]	0.4063*** [3.5443]	0.1502 [0.9697]	0.1057*** [2.3127]
h = 6	76.5975*** [9.8644]	1.4884*** [2.0643]	0.4087*** [3.5750]	0.1492 [0.9744]	0.1060*** [2.3253]
h = 12	75.6083*** [9.8203]	1.9239*** [2.6289]	0.4091*** [3.5996]	0.1469 [0.9824]	0.1076*** [2.3724]
h = 24	73.8967*** [9.7646]	1.9899*** [2.7442]	0.4041*** [3.6023]	0.1417 [0.9906]	0.1089*** [2.4273]
Model 5 vs. Model 2					
In-sample	77.4870*** [9.9032]	1.6817*** [2.6351]	0.4112*** [3.6204]	0.1535 [0.9614]	0.1039*** [2.2691]
h = 1	77.3159*** [9.8956]	1.7098*** [2.6883]	0.4107*** [3.6202]	0.1528 [0.9607]	0.1041*** [2.2761]
h = 3	77.0790*** [9.8958]	1.7062*** [2.7038]	0.4110*** [3.6307]	0.1513 [0.9592]	0.1057*** [2.3141]
h = 6	76.7725*** [9.9030]	1.6612*** [2.6634]	0.4136*** [3.6637]	0.1503 [0.9643]	0.1060*** [2.3267]
h = 12	75.7821*** [9.8587]	2.3743*** [3.3698]	0.4157*** [3.7049]	0.1482 [0.9732]	0.1075*** [2.3734]
h = 24	74.0551*** [9.8010]	2.6164*** [3.6630]	0.4105*** [3.7058]	0.1414 [0.9707]	0.1089*** [2.4292]
Model 5 vs. Model 3					
In-sample	0.1186*** [2.2018]	2.8724*** [2.5486]	0.4547*** [3.2649]	0.2978 [0.9986]	0.1186*** [2.2018]
h = 1	0.1188*** [2.2079]	2.8556*** [2.5446]	0.4542*** [3.2648]	0.2971 [1.0003]	0.1188*** [2.2079]
h = 3	0.12034*** [2.2399]	2.8693*** [2.5578]	0.4539*** [3.2703]	0.2955 [1.0028]	0.1203*** [2.2399]
h = 6	0.1202*** [2.2455]	2.8189*** [2.5645]	0.4564*** [3.2979]	0.2908 [0.9985]	0.1202*** [2.2455]
h = 12	0.1218*** [2.2871]	2.9667*** [2.7568]	0.4578*** [3.3285]	0.2848 [1.0012]	0.1218*** [2.2871]
h = 24	0.1232*** [2.3389]	2.9446*** [2.8556]	0.4520*** [3.3298]	0.2730 [1.0039]	0.1232*** [2.3389]

Note: Model 1 is the model without control; Model 2 is the model with control; Model 3 is the model with asymmetry; Model 5 is the random walk model without drift. The Clark and West (2007) test is a one-sided test, and the null hypothesis of a zero coefficient (implying equality in forecast accuracy of two competing models) is rejected if this statistic is greater than the critical value for any of the conventional levels where it is +1.282, +1.645, and +2.00 for 10%, 5%, and 1% levels, respectively (Clark & West, 2007). Values in square brackets [] are for *t*-statistics.
***1% level.
**5% level.
*10% level.

exchange rate that accounts for stock return differential is more likely to outperform the one that ignores it, such as the historical average and random walk models. Like the RMSE statistics, the C–T statistics seem to increase with the consideration of the mentioned control variable (oil price movements) and asymmetry effect in the stock differential series. This outcome is in line with the evidence of Chen and Hsu (2019) albeit with a focus on most traded currencies and without considering asymmetry effect. An extension of the Chen and Hsu (2019) study to capture the emerging markets of the BRICS offers is crucial for possible generalization of the predictability of stock markets for exchange rates.

Lastly, we test for the significance of the difference in the forecast errors of each of the stock-based models and the benchmark models using the C–W test and we present the results in Tables 6 and 7. Like the C–T statistics, the C–W coefficients are predominantly positive, thus

TABLE 8 Forecast performance results for UK

Forecast horizon	Single measure method: RMSE				
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
In-sample	2.0985	2.0871	2.0963	2.1275	2.1301
h = 1	2.1000	2.0885	2.0978	2.1291	2.1317
h = 3	2.1005	2.0891	2.0984	2.1297	2.1323
h = 6	2.1070	2.0956	2.1048	2.1360	2.1390
h = 12	2.1288	2.1173	2.1262	2.1574	2.1598
h = 24	2.1274	2.1166	2.1248	2.1554	2.1575

Pairwise method using the Campbell and Thompson (2008)						
Forecast Horizon	**Model 4 vs. Model 1**	**Model 4 vs. Model 2**	**Model 4 vs. Model 3**	**Model 5 vs. Model 1**	**Model 5 vs. Model 2**	**Model 5 vs. Model 3**
In-sample	0.0136	0.0190	0.0146	0.0147	0.0201	0.0158
h = 1	0.0136	0.0190	0.0146	0.0148	0.0202	0.0158
h = 3	0.0136	0.0190	0.0146	0.0149	0.0202	0.0159
h = 6	0.0135	0.0189	0.0146	0.0149	0.0203	0.0160
h = 12	0.0132	0.0186	0.0145	0.0143	0.0196	0.0155
h = 24	0.0129	0.0179	0.0141	0.0139	0.0189	0.0151
Pairwise method using the Clark and West (2007)						
In-sample	0.2449*** [3.4283]	0.3408*** [4.0834]	0.2635*** [3.3844]	0.2607*** [3.6345]	0.3566*** [4.3046]	0.2792*** [3.5148]
h = 1	0.2455*** [3.4388]	0.3413*** [4.0918]	0.2637*** [3.3900]	0.2617*** [3.6512]	0.3575*** [4.3186]	0.2799*** [3.5260]
h = 3	0.2455*** [3.4434]	0.3412*** [4.0961]	0.2636*** [3.3930]	0.2619*** [3.6586]	0.3577*** [4.3256]	0.2800*** [3.5315]
h = 6	0.2453*** [3.4431]	0.3414*** [4.1017]	0.2640 [3.4008]	0.2632*** [3.6788]	0.3594*** [4.3484]	0.2818*** [3.5578]
h = 12	0.2452*** [3.4532]	0.3417*** [4.1208]	0.2657*** [3.4348]	0.2603*** [3.6494]	0.3569*** [4.3334]	0.2807*** [3.5569]
h = 24	0.2418*** [3.4295]	0.3363*** [4.0827]	0.2618*** [3.4084]	0.2558*** [3.6117]	0.3506*** [3.2853]	0.2758*** [3.5182]

Note: Model 1 is the model without control; Model 2 is the model with control; Model 3 is the model with asymmetry; Model 4 is the Historical Average model, and Model 5 is random walk model without drift. For the root mean square error (RMSE) measure, lower values are preferred. For the Campbell and Thompson (2008) [C–T] test, positive values imply superior performance of the unrestricted model over the restricted model whereas negative values imply otherwise. The Clark and West (2007) [C–W] test is a one-sided test, and the null hypothesis of a zero coefficient (implying equality in forecast accuracy of two competing models) is rejected if this statistic is greater than the critical value for any of the conventional levels where it is +1.282, +1.645, and +2.00 for 10%, 5%, and 1% levels, respectively (Clark & West, 2007). Values in square brackets [] are for *t*-statistics.

***1% level.

**5% level.

*10% level.

ascertaining the potential of the stock–based predictive model in enhancing the accuracy of exchange rate forecasts of the BRICS relative to the benchmark models. This significance of the C–W test is largely evident for Brazil, India, and Russia (after accounting for asymmetry effect). The conclusion here is straightforward. The various forecast measures lend support to the inclusion of stock return differential when modeling and forecasting movements in exchange rates of emerging markets particularly those drawn from the BRICS bloc. In other words, accounting for the predictor series can improve the forecast accuracy of exchange rates. Two policy implications can be drawn from this outcome. First, financial analysts seeking for models that will improve their forecasts of exchange rate possibly for the purpose of portfolio diversification particularly between domestic and foreign stock markets will find our results insightful. Second, policy makers who are constantly pressured on how to stabilize exchange rate particularly for countries with managed floating exchange system may find the study useful as it offers an alternative approach, among other existing options, of determining when foreign exchange (FX) intervention will be required. For instance, where exchange rate is expected to depreciate based on the forecast from the stock-based predictive model, relevant policy authority may forestall or mitigate such depreciation via policy actions targeted at reducing domestic supply of FX, among others.

4.3 | Additional results

For robustness purpose, we consider a developed economy, the UK economy, in order to complement the analysis rendered for the emerging economies of the BRICS. The reference country, the USA, remains unchanged. Therefore, the stock differential is computed as the difference between the (FTSE All Share Stock Index [ALSI]) stock returns of the UK (which is considered as the domestic stock market in this case derived from Global Financial Data) and that of the USA (i.e., the foreign stock market). Hence, we further provide additional results using the case of economies of the same status, that is, UK stock return differential relative to the USA. Another important attraction to the UK among other developed economies (aside from the USA, which is the reference country here) is the availability of a long range of data of over two centuries dating back to 1791. The results that utilize the entire dataset, albeit with the control variable (oil price changes) due to data limitation, are presented in the appendix (see Table A1). Notwithstanding, we consider a reduced size starting from 1859 (over a century) being the earliest period for the West Texas Intermediate (WTI) crude oil price (obtained from Global Financial Data as well) in order to accommodate the stock-based predictive model with control variable. We focus on the forecast evaluation of the alternative models previously analyzed for the BRICS and the results are presented in Table 8. The forecast performance results from both the single method using RMSE and the pairwise methods (i.e., C–T and C–W) consistently support our earlier findings. All the variants of the stock-based model outperform the benchmark models both for the in-sample and out-of-sample predictability. A look at Table A1 in the appendix section of the paper further suggests that the conclusion remains the same irrespective of the data sample. Given the consideration of both emerging and developed economies in this study, our evidence offers some level of generalization about the predictive prowess of stock markets for forecasting exchange rate.

5 | CONCLUSION

This study seeks to examine the predictability of stock return differential for exchange rates of the BRICS. We rely on the UEP hypothesis in the formulation of a bivariate predictive model that links exchange rate to stock return differential. Although several empirical studies have examined the validity or otherwise of the UEP hypothesis (see, e.g., Cappiello & De Santis, 2005, 2007; Chen & Hsu, 2019; Curcuru et al., 2014; Gelman et al., 2015; Hau & Rey, 2006; Kim, 2011), their analyses are limited to in-sample predictability, which does not offer sufficient information about the out-of-sample forecast ability of stock markets for exchange rates. This is the motivation for the study, and the only exception is Chen and Hsu (2019) albeit with a focus on the developed economies. In addition to considering emerging economies of the BRICS, we also account for asymmetry effect, which assumes that exchange rate may respond differently to positive and negative stock return differentials. We also control for a common global factor (oil price) in the estimation process, and thus, we arrive at three variants of the stock-based model for exchange rate while the historical average and driftless random walk random models constitute the benchmark models. The forecast evaluation involves comparing the variants of the stock-based model with the benchmark models using both the single (RMSE) and pairwise Clark and West (2007) and Campbell and Thompson (2008) forecast measures while multiple out-of-sample forecast horizons (1, 3, 6,12, and 24 months) are analyzed. Our results support a positive relationship between stock return differential and exchange rate return for three of the BRICS countries, namely, Brazil, India, and South Africa, thus validating the UEP hypothesis whereas a contrasting evidence is observed for China as well as Russia (after accounting for "asymmetry effect"). The significance of the predictor series is evident for both the in-sample and out-of-sample predictability while accounting for movements in oil price and asymmetry may further improve the forecast accuracy. We note that financial/investment analysts may find the results useful for the purpose of portfolio diversification between domestic and foreign portfolios, likewise policy makers in terms of stabilizing exchange rates.

An extension of this study that utilizes sectoral stock data and by implication panel data forecasting techniques and or forecast combination/averaging methods would further enrich the literature on the subject. This may however require using trade-weighted exchange rates with the relative sectoral trading volume for domestic and foreign stock markets used as the weighting scheme to accommodate some level of heterogeneity in both exchange rate and stock return differential. This is an area we set aside for future research.

6 | ACKNOWLEDGMENTS

Juncal Cuñado gratefully acknowledges financial support from Ministerio de Economía y Competitividad, Spain (ECO2017-83183-R).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. Some of the data are not publicly available due to privacy or ethical restrictions.

ORCID

Afees A. Salisu https://orcid.org/0000-0003-0619-6545
Juncal Cuñado https://orcid.org/0000-0002-1597-9755
Rangan Gupta https://orcid.org/0000-0001-5002-3428

ENDNOTES

[1] Evidence of a negative correlation between stock return differentials and exchange rates is also found in the literature (see, e.g., Cenedese et al., 2016).

[2] In 2001, the term BRIC was coined for Brazil, Russia, India, and China. South Africa joined this group of countries in 2010, leading to BRICS.

[3] Note that BRICS countries include both the largest and fastest growing energy producers and consumers in the world. Russia is the world's Number 2 net exporter of crude oil and China and India stand as the world's first and third net crude oil importers (International Energy Agency [IEA], 2019).

[4] Salisu et al. (2019, 2020) provide evidence in favor of the inclusión of a global (oil price) factor in the predictive model of exchange rate movements.

[5] In any case, expressing the series in return form helps to circumvent the problem of unit root typical of most financial series expressed in price index form. Note that we also follow Chen and Hsu (2019) in this regard.

[6] (http://www.globalfinancialdata.com/) The names of the respective stock indices used are Brazil: Brazil *Bolsa de Valores de Sao Paulo* (BOVESPA) Stock Index; Russia: MOEX Russia Composite Index; India: Bombay Stock Exchange (BSE) Index; China: Shanghai Stock Exchange (SSE) Composite Index; South Africa: FTSE/Johannesburg Stock Exchange (JSE) All-Share Index, and; US: S&P 500 Index.

[7] See Chen and Hsu (2019) for a review of related studies on the subject.

[8] Within the context of UEP, a contemporaneous relationship is assumed between exchange rate and stock return differentials. Thus, in addition to the predictability objective, we are also able to test the UEP condition for the countries under examination.

[9] The outcome of additional preliminary tests such as persistence, endogeneity bias, and conditional heteroscedasticity tests as discussed in Westerlund and Narayan (2012, 2015), whose results are available on request, also favors the chosen estimator.

[10] These are standard forecast measures for nested models, which is the case here.

[11] According to Rossi (2013), "the toughest benchmark is the random walk without drift" in the exchange rate predictability, hence, its consideration as one of the benchmark models adopted in this study. We owe this additional analysis involving the driftless random walk to one of the anonymous reviewers who suggested this consideration in the earlier draft of the manuscript.

REFERENCES

Abhyankar, A., Sarno, L., & Valente, G. (2005). Exchange rates and fundamentals: Evidence on the economic value of predictability. *Journal of International Economics*, *66*(2), 325–348. https://doi.org/10.1016/j.jinteco.2004.09.003

Aftab, M., Ahmad, R., & Ismail, I. (2018). Examining the uncovered equity parity in the emerging financial markets. *Research in International Business and Finance*, *45*, 233–242. https://doi.org/10.1016/j.ribaf.2017.07.154

Bacchetta, P., Van Wincoop, E., & Beutler, T. (2010). Can parameter instability explain the Meese–Rogoff puzzle? In *NBER International Seminar on Macroeconomics* (Vol. 6(1)) (pp. 125–173). Chicago, Illinois: University of Chicago Press.

Baur, D. G., & Miyakawa, I. (2013). *International investors, exchange rates and equity prices*. (Working Paper Series 178). Sydney: Finance Discipline Group, UTS Business School, University of Technology. https://doi.org/10.2139/ssrn.2389964

Berkowitz, J., & Giorgianni, L. (2001). Long-horizon exchange rate predictability? *Review of Economics and Statistics*, *83*(1), 81–91. https://doi.org/10.1162/003465301750160054

Bohn, H., & Tesar, L. L. (1996). US Equity investment in foreign markets: Portfolio rebalancing or return chasing? *American Economic Review*, *86*(2), 77–81.

Campbell, J. Y., & Thompson, S. B. (2008). Predicting excess stock returns out of sample: Can anything be at the historical average? *Review of Financial Studies*, *21*(4), 1509–1531. https://doi.org/10.1093/rfs/hhm055

Cappiello, L. & De Santis, R. A. (2005). Explaining exchange rate dynamics: The uncovered equity return parity condition. (Working Paper Series 0529). Frankfurt, Germany: European Central Bank.

Cappiello, L. & De Santis, R. A. (2007). The uncovered return parity condition. (Working Paper Series 0812). Frankfurt, Germany: European Central Bank.

Cenedese, G., Payne, R., Sarno, L., & Valente, G. (2016). What do stock markets tell us about exchange rates? *Review of Finance*, *20*(3), 1045–1080. https://doi.org/10.1093/rof/rfv032

Chabot, B., Ghysels, E. & Jagannathan, R. (2014). Momentum trading, return chasing, and predictable crashes. (NBER Working Papers 20660). Cambridge, MA: National Bureau of Economic Research.

Chen, S., & Hsu, C. (2019). Do stock markets have predictive content for exchange rate movements? *Journal of Forecasting*, *38* (7), 699–713. https://doi.org/10.1002/for.2592

Clark, T. E., & West, K. D. (2007). Approximately normal tests for equal predictive accuracy in nested models. *Journal of Econometrics*, *138*(1), 291–311. https://doi.org/10.1016/j.jeconom.2006.05.023

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*, *47*, 86–99. https://doi.org/10.1016/j.jimonfin.2014.04.009

Ferraro, D., Rogoff, K., & Rossi, B. (2015). Can oil prices forecast exchange rates? An empirical analysis of the relationship between commodity prices and exchange rates. *Journal of International Money and Finance*, *54*, 116–141.

Gelman, M., Jochem, A., Reitz, S., & Taylor, M. P. (2015). Real financial market exchange rates and capital flows. *Journal of International Money and Finance*, *54*(Supplement C), 50–69.

Griffin, J. M., Nardari, F., & Stulz, R. M. (2004). Are daily cross-border equity flows pushed or pulled? *Review of Economics and Statistics*, *86*(3), 641–657. https://doi.org/10.1162/0034653041811725

Hau, H., & Rey, H. (2006). Exchange rates, equity prices, and capital flows. *Review of Financial Studies*, *19*(1), 273–317. https://doi.org/10.1093/rfs/hhj008

IEA. (2019). *World Energy Outlook 2019*. Paris: OECD Publishing. https://doi.org/10.1787/caf32f3b-en

Jiang, M. (2019). A comparative analysis of the exchange rate system of the BRICS. *Modern Economy*, *10*(04), 1168–1177. https://doi.org/10.4236/me.2019.104079

Kilian, L., & Taylor, M. P. (2003). Why is it so difficult to beat the random walk forecast of exchange rates? *Journal of International Economics*, *60*(1), 85–107. https://doi.org/10.1016/S0022-1996(02)00060-0

Kim, H. (2011). The risk adjusted uncovered equity parity. *Journal of International Money and Finance*, *30*(7), 1491–1505. https://doi.org/10.1016/j.jimonfin.2011.06.020

Malliaropulos, D. (2008). International stock return differentials and real exchange rate changes. *Journal of International Money and Finance*, *17*, 493–511.

Meese, R. A., & Rogoff, K. S. (1983a). Empirical exchange rate models of the seventies: Do they fit out of sample? *Journal of International Economics*, *14*, 3–24. https://doi.org/10.1016/0022-1996(83)90017-X

Meese, R. A., & Rogoff, K. S. (1983b). The out-of-sample failure of empirical exchange rate models: sampling error or misspecification? In J. A. Frenkel (Ed.), *Exchange rates and international macroeconomics* (pp. 67–112). University of Chicago Press: Chicago and London.

Melvin, M., & Prins, J. (2015). Equity hedging and exchange rates at the London 4 p.m. fix. *Journal of Financial Markets*, *22*, 50–72. https://doi.org/10.1016/j.finmar.2014.11.001

Moe, T., Maasry, C., & Tang, R. (2010). EM equity in two decades: A changing landscape. Goldman Sachs Global Economics Paper No 204.

Moosa, I. (2013). Why is it so difficult to outperform the random walk in exchange rate forecasting? *Applied Economics*, *45*(23), 3340–3346. https://doi.org/10.1080/00036846.2012.709605

Moosa, I., & Burns, K. (2014c). A reappraisal of the Meese–Rogoff puzzle. *Applied Economics*, *46*(1), 30–40. https://doi.org/10.1080/00036846.2013.829202

Moosa, I. A., & Burns, K. (2012). Can exchange rate models outperform the random walk? Magnitude, direction and profitability as criteria. *International Economics*, *65*, 473–490.

Moosa, I. A., & Burns, K. (2014a). The unbeatable random walk in exchange rate forecasting: Reality or myth? *Journal of Macroeconomics*, *40*, 69–81.

Moosa, I. A., & Burns, K. (2014b). Error correction modelling and dynamic specifications as a conduit to outperforming the random walk in exchange rate forecasting. *Applied Economics*, *46* (25), 3107–3118. https://doi.org/10.1080/00036846.2014.922675

Narayan, P. K., & Liu, R. (2015). A unit root model for trending time-series energy variables. *Energy Economics*, *50*, 391–402. https://doi.org/10.1016/j.eneco.2014.11.021

Rossi, B. (2013). Exchange rate predictability. *Journal of Economic Literature*, *51*, 1063–1119. https://doi.org/10.1257/jel.51.4.1063

Salisu, A. A., Adekunle, W., Alimi, W. A., & Emmanuel, Z. (2019). Predicting exchange rate with commodity prices: New evidence from Westerlund and Narayan (2015) estimator with structural breaks and asymmetries. *Resources Policy*, *62*(C), 33–56. https://doi.org/10.1016/j.resourpol.2019.03.006

Salisu, A. A., Cuñado, J., Isah, K., & Gupta, R. (2020). Oil price and exchange rate behaviour of the BRICS. *Emerging Markets Finance & Trade*, 1–10. https://doi.org/10.1080/1540496X.2020.1850440

Ülkü, N., Fatullayev, S., & Diachenko, D. (2016). Can risk-rebalancing explain the negative correlation between stock return differential and currency? Or does source status derive it? *Journal of Financial Markets*, *27*, 28–54. https://doi.org/10.1016/j.finmar.2015.07.001

UNCTAD. (2019). Special economic zones. World Investment Report.

Westerlund, J., & Narayan, P. K. (2012). Does the choice of estimator matter when forecasting returns? *Journal of Banking and Finance*, *36*, 2632–2640. https://doi.org/10.1016/j.jbankfin.2012.06.005

Westerlund, J., & Narayan, P. K. (2015). Testing for predictability in conditionally hetoroscedasticity stock returns. *Journal of Financial Econometrics*, *13*, 342–375. https://doi.org/10.1093/jjfinec/nbu001

Wong, D. K. T., & Li, K. (2013). Comparing the performance of relative stock return differential and real exchange rate in two financial crises. *Applied Financial Economics*, *20*(1–2), 137–150.

AUTHOR BIOGRAPHIES

Afees A. Salisu, PhD, is the current director and research professor of the Centre for Econometric and Allied Research (CEAR), University of Ibadan. He is also affiliated with the Global Humanistic University (GHU) as a university professor and doctoral advisor and research fellow of the Institute of Business Research, University of Economics Ho Chi Minh City, Vietnam. He is ranked among top 5% research economists in the world (see https://ideas.repec.org/f/psa997.html), top 1% in Africa (https://ideas.repec.org/cgi-bin/rank.cgi?psa997&KxXC), and top 1% (https://ideas.repec.org/cgi-bin/rank.cgi?psa997&KxXC) in Nigeria based on the ranking by *Research Papers in Economics* (RePEc) network, which archives the largest database of economists in the world.

Juncal Cuñado is a PhD in Applied Economics and full professor in the Economics Department at the University of Navarra, Spain. She has been visiting scholar at the Economics Department at University of California, San Diego, OXCARRE (University of Oxford), and the Smith School of Enterprise and the Environment at the University of Oxford. She has published papers in relevant international journals, such as *Energy Economics*, *Social Indicators Research*, *Journal of Policy Modeling*, *Journal of Cleaner Production*, *Energy Policy*, *Ecological Economics*, and *Journal of Economic Psychology*.

Kazeem Isah is currently a PhD student at the University of KwaZuluNatal and a research fellow of the Centre for Econometric and Allied Research, University of Ibadan. He majors in Energy Economics, Macroeconomics and Monetary Economics and has published articles in related journals such as *Energy Economics*, *Economic Modelling*, and *Energy*, among others.

Rangan Gupta is a professor at the Department of Economics, University of Pretoria, South Africa. He completed his PhD in May 2005 from the Department of Economics, University of Connecticut, USA. He then joined the Department of Economics, University of Pretoria, as a senior lecturer in August 2005. He obtained his BSc (honors) degree in Economics from the R.K.M.R College, Narendrapur, India, and MSc degree in Economics from the University of Calcutta, India. His academic interests are mainly monetary theory and policy, and time series econometrics, and he has authored and coauthored many articles in internationally accredited peerreviewed journals and book chapters in these areas of research. He is also associated with multiple journals as associate editor and editorial boards.

How to cite this article: Salisu, A. A., Cuñado, J., Isah, K., & Gupta, R. (2021). Stock markets and exchange rate behavior of the BRICS. *Journal of Forecasting*, *40*(8), 1581–1595. https://doi.org/10.1002/for.2795

APPENDIX A

TABLE A1 Forecast performance results for UK with August 1791 the start date

	Single measure method: RMSE				
Forecast horizon	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
In-sample	2.6839	Not applicable	2.6847	2.6792	2.6853
h = 1	2.6833		2.6840	2.6785	2.6846
h = 3	2.6820		2.6827	2.6772	2.6833
h = 6	2.6800		2.6807	2.6753	2.6814
h = 12	2.6762		2.6769	2.6715	2.6775
h = 24	2.6685		2.6692	2.6638	2.6699
Pairwise method using the Campbell and Thompson (2008)						
Forecast Horizon	**Model 4 vs. Model 1**	**Model 4 vs. Model 2**	**Model 4 vs. Model 3**	**Model 5 vs. Model 1**	**Model 5 vs. Model 2**	**Model 5 vs. Model 3**
In-sample	0.0002	Not applicable	0.0020	0.0004	Not applicable	0.0022
h = 1	0.0003		0.0020	0.0004		0.0022
h = 3	0.0003		0.0020	0.0004		0.0022
h = 6	0.0003		0.0020	0.0004		0.0022
h = 12	0.0003		0.0020	0.0004		0.0022
h = 24	0.0003		0.0020	0.0004		0.0022
Pairwise method using the Clark and West (2007)						
In-sample	0.0075 [0.3006]	Not applicable	0.0585 [1.3515]	0.0089 [0.3408]	Not applicable	0.0591* [1.4224]
h = 1	0.0075 [0.3007]		0.0585 [1.3516]	0.0089 [0.3408]		0.0590* [1.4224]
h = 3	0.0075 [0.3008]		0.0585 [1.3517]	0.0089 [0.3408]		0.0590* [1.4224]
h = 6	0.0075 [0.3007]		0.0583 [1.3515]	0.0089 [0.3408]		0.0589* [1.4224]
h = 12	0.0075 [0.3007]		0.0582 [1.3514]	0.0089 [0.3408]		0.0587* [1.4224]
h = 24	0.0075 [0.3020]		0.0578 [1.3512]	0.0088 [0.3421]		0.0584* [1.4221]

Note: Model 1 is the model without control; Model 2 is the model with control; Model 3 is the model with asymmetry; Model 4 is the historical average model, while Mode 5 is the random walk model without drift. For the root mean square error (RMSE) measure, lower values are preferred. For the Campbell & Thompson, 2008 [C–T] test, positive values imply superior performance of the unrestricted model over the restricted model whereas negative values imply otherwise. The Clark & West, 2007 [C–W] test is a one-sided test, and the null hypothesis of a zero coefficient (implying equality in forecast accuracy of two competing models) is rejected if this statistic is greater than the critical value for any of the conventional levels where it is +1.282, +1.645, and +2.00 for 10%, 5%, and 1% levels, respectively (Clark & West, 2007). Values in square brackets [] are for *t*-statistics.

***1% level.

**5% level.

*10% level.