An analysis of the unbiased forward rate hypothesis in developed and emerging economies

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An analysis of the unbiased forward rate hypothesis (UFRH) in developed and emerging economies

by

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Abstract

This study assesses whether the unbiased forward rate hypothesis (UFRH) holds in its strong or weak form in selected developed and emerging economies. Moreover, the paper assesses whether this hypothesis, or the relationship between the forward and spot exchange rates, is better specified by a linear or nonlinear model. The paper makes use of the smooth transition error correction model (STECM) to account for long-run relationship and asymmetric adjustment between the two exchange rates. The results of the empirical analysis show the possibility of nonlinear cointegration between the spot and forward exchange rates in a number of developed and emerging economies. In addition, the results reveal that the magnitude of the speed of adjustment to cancel arbitrage opportunities is higher in emerging than in developed markets. This occurs because the size of arbitrage profit is higher in emerging markets compared to developed markets.

1. Introduction

The unbiased forward rate hypothesis (UFRH) is one of the most tested hypotheses in international finance. The hypothesis holds that the forward exchange rate should be an unbiased predictor of the future spot exchange rate, given the assumption of risk neutrality and rational expectation. A number of studies show that the UFRH does not hold (see Delcoure, Barkoulas, Baum and Chakraborty, 2003, Spagnolo, Psaradakis and Sola, 2005 and Ho and Mo, 2016). The failure of the forward rate unbiasedness hypothesis has captured a significant amount of attention in international finance as this hypothesis has major implications for the market efficient hypothesis, forecasting future spot exchange and for market participants, such as hedgers in the foreign exchange market.

Given that the UFRH is linked to market efficiency (see Geweke and Feige, 1979, Hakkio and Rush, 1989 and Phillips, McFarland, and McMahon, 1996), academics, policy makers, market participants and organisations have questioned the efficiency of the forward exchange rate. The forward market efficiency requires that the forward rate be an unbiased predictor of the future spot rate. Phillips, McFarland, and McMahon (1996) investigated the forward market efficiency by testing the UFRH in selected major currencies for the period 1 May 1922 to 30 May 1925. The authors find that the hypothesis was only empirically supported by the British pound and that other currencies rejected the UFRH. However, early empirical studies, Frenkel (1977) and Levich (1979), that have looked at UFRH provided support for the proposition that the forward exchange rate could be used to predict future spot exchange rate therefore further indicating that the forward exchange rate market was efficient , Hodricks (1987).

The failure of UFRH implies that the market is inefficient and that investors can make abnormal profit or returns. If the hypothesis is to hold, the risk associated with the exchange rate would have no negative impact on the expected profit of hedgers. However if it does not hold, this will impact the expected profit of hedgers, which may for instance involve risk premium payment, Zacharatos and Sutcliffe (2002).

Studies that have investigated the relation between the spot and forward exchange rate often make a distinction between the strict and weak form of testing the UFRH. The UFRH is said to be strict if there is a one to one relationship between the spot and forward exchange rate in equilibrium. This condition is often difficult to verify and test empirically. However, the weak version of the UFRH assumes that the spot and forward exchange rate are cointegrated. This implies that there exist a long run relationship between the spot and forward exchange rate, Spagnolo, Psaradakis, and Sola (2005) and Gregory and McCurdy (1984) .

Given the controversial findings in a number of studies that tested the UFRH, different reasons are attributed why the hypothesis does not hold. For example, Delcoure, Barkoulas, Baum and Chakraborty (2003) suggested that addressing model misspecification would solve the failure of the UFRH. it is in that context that the authors suggest the use of a linear multivariate unit root test and Johansen likelihood ratio test for testing the UFRH. Aggarwal et al. (2009) attributed the failure of UFRH to statistical procedure, explaining that traditional models used in previous studies failed to correct for non-stationarity and nonnormality in the dataset. Baldwin (1990) suggests the use of a nonlinear to solve issues of international puzzle, given that linear models are unable to capture potential nonlinear adjustment that may exist between the spot and forward exchange rate, for example. Moreover, the author shows that the existence of transaction cost is identified as one of the critical factors to explain nonlinear adjustment in the foreign exchange market.

it is in that context that Baldwin (1990) developed a model that emphasises the role of transaction cost in creating a band for investors decisions. The model suggests that investors will only trade if the deviations from the UIP is above a given transaction cost band. Thus, UIP hypothesis holds when equilibrium is established in the foreign exchange market due to investors’ action. Moreover, Duma (1992) applied the same principles of nonlinear adjustment to the purchasing power parity (PPP) hypothesis and found that in the presence of a transaction cost band, deviations from the PPP may persist.

Moreover, proponents of a nonlinear adjustment such as Bonga-Bonga (2009) argue that the UIP is a pre-condition for the UFRH to hold; therefore these models can similarly be applied to the UFRH puzzle it is in that context that this study applies the smooth transition error correction model (STECM) to assess the nonlinear adjustment between the spot and forward rates. This assessment is necessary to investigate whether there is a long-term relationship between the spot and forward rates, thus, whether the UFRH holds.

Although nonlinear model have been developed and applied to other international finance puzzles such as the UIP and PPP, to the best of our knowledge, no study has ever applied the STECM in testing the UFRH in developed and emerging economies.

Emerging markets exchange rate are considered to be more risky compared to developed markets. Thus, the nonlinear adjustment process between the spot and forward rate may differ between the two markets. In other words, the risk premium in emerging markets is expected to be higher than that in developed markets, Frankel and Poonawala (2010). Given this differences and the direct implication exchange rate have on the expected return, this study will help investors understand and identify the different risk return trade-off offered on currency deposits by emerging and developed economies. Therefore, providing valuable lessons in understanding which markets provide better expected return and which markets offer better arbitrage opportunities.

Given the shortcomings from previous studies, this study will make use of the nonlinear smooth transition error correction model (STECM) to examine the band of arbitrage profit in the forward exchange market determined by forward premium and the subsequent speed of adjustment for nonlinear adjustment toward equilibrium between the spot and forward rates. it is important to note that the size of the forward premium determines the extent to which deviations from the UFRH can occur and persist. When the forward premium is large, the spread of this arbitrage opportunity becomes larger, which would induce investors to trade on them and deviations from the UFRH becomes increasingly mean reverting, Azouzi, Kumar, and Aloui (2011).

The aim of this study is therefore in three folds. Firstly, the study assess whether the UFRH holds in its strong or weak form in selected developed and emerging economies i.e. whether there exist a long term relationship between forward and future spot rate in these economies. Secondly the paper investigates whether this relationship is better specified by a nonlinear rather than a linear model. Thirdly, with the use of the STECM, the study will uncover the band of arbitrage profit in the forward exchange market in developed and emerging economies and the speed to which arbitrage profits are precluded and equilibrium is established between the spot and forward rates.

The study follows Li, Ghoshray and Morley (2013) in selecting developed and emerging economies. Thus, the three developed economies, Germany, British and Japan were selected because of the vital role these currencies play in the forward exchange rate market. Russia, China and South Africa were selected on the basis of being members of BRICS as these countries are considered major emerging economies.

The remainder of this study covers the following sections; section 2 presents previous studies discussing factors and explanations for the failure of the UFRH and the reason for the use of nonlinear adjustment model. Section 3 covers the methodology utilised. Following the above section, a description of the dataset is given with the main findings of the study in section 4 and 5. Lastly section 6 presents concluding remarks and recommendations.

2. Literature review

A number of studies have been conducted in order to test the UFRH. For example, Phillips and McFarland (1997), Choi and Zivot (2007), Bonga-Bonga (2009), Chakraborty (2009), Frankel and Poonawala (2010) and Li, Ghoshray and Morley (2013). Literature that tested the UFRH has identified several factors in explaining the contradicting results observed when testing the UFRH namely model misspecifications, structural breaks, systematic errors by market participant and time varying risk premium.

2.1 Model Misspecification

Proponents of model misspecification approach contended that the failure to use the correct model could lead to the rejection or support of the UFRH based on inaccurate and biased estimations. For example, Phillips and McFarland (1997) find that their results rejects the UFRH in Australia over the period 1984 to 1991 when implementing a robust statistical approach to regression. Barnhart and Szakmary (1991) uses percentage change specification in error correction model to examine the UFRH for the period 1974 to 1988. Results obtained strongly rejected the UFRH for all currencies.

Delcoure, Barkoulas, Baum and Chakraborty (2003) re-examined the failure of UFRH for eight major currencies in the post Bretton era, using a new multivariate unit root test and Johansen likelihood ratio test. However, they find strong evidence that UFRH is rejected for all currencies with the exception of the Italian lira, Swiss franc and Deutsche mark.

Bonga-Bonga (2008) shows the importance of using a nonlinear model in testing the UFRH. The author compares the forecasting ability of the Kalma filter technique with the random walk and ordinary least square (OLS) model for estimating the relationship between the rand/dollar forward exchange rate and future spot rate spanning from 1996 to 2003. The study employs two performance criterions; the root mean square error and mean square error. Results showed that the Kalma filter outperformed other models indicating the importance of a nonlinear model in predicting future spot rate in the context of the UFRH.

Although numerous studies supported the argument of model misspecification, they generally did not agree on how the model should be specified Delcoure, Barkoulas, Baum and Chakraborty (2003), Bonga-Bonga (2009) and Zacharatos and Sutcliffe (2002). Some studies advocate for a linear approach, with others suggest that a linear model may fail to capture the existence of a nonlinear relation.

For example, Bonga-Bonga (2009) utilises a nonlinear smooth transition model to analyse the UFRH for the South African rand against the US dollar for the period 1994 to 2008. This study suggest that previous studies found strong evidence for a nonlinear adjustment and that there is a regime where the UFRH holds.

More recently, other studies have applied a nonlinear model in other international finance puzzles. For example, Baillie and Kilic (2006) find that based on limits to speculation, a nonlinear model is appropriate for modelling the UIP hypothesis. Utilising a smooth transition regression, these authors find that the UIP fails to hold when in comparison to other investment opportunity because deviations from UIP does not have a large Sharpe ratio to induce investors to trade on these deviations.

Amri (2008) uses a logistic smooth transition regression to examine the forward premium anomaly for several major currencies. The data sample is composed of weekly three months and six-month forward rate and spot rate and results suggest that there exist three regimes. The inner regime characterised by a band while the other two outer regimes are characterised by the forward premium. The forward premium is high enough in the outer regime and is consistent with the UIP holding in those regimes.

When examining the relationship between interest rate differentials and expected change in exchange rate Li, Ghoshray and Morley (2013) uses a nonlinear smooth transition regression model (STR). The idea is that previous studies relied on a linear adjustment; however, failed to recognize that factors such as policy actions by central bank, transaction cost and limits to speculation has nonlinear implications for this relation. This study finds strong evidence of a nonlinear adjustment between expected exchange rate and interest rate differential. Given that the UIP is a pre-condition for the UFRH to hold, this nonlinear adjustment process can also be applied to the UFRH.

2.2 Structural changes

Another important reason why the UFRH does not hold is the failure to account for structural changes. For example, Sakoulis and Zivot (2001) argue that the persistent failure of UFRH is exacerbated by the presence of structural breaks. The authors apply the UFRH test to G7 countries using time varying parameter specification for the autoregressive model and multiple stochastic models for the period 1973 to 2000. Contrary to previous studies, the study's finds that correcting for the presence of structural breaks results in the forward rate being less biased.

Choi and Zivot (2007) evaluates the forward unbiased hypothesis by taking into account long memory and structural changes. This study follows a two-approach methodology; firstly, testing long memory in the absence of structural changes and secondly in the presence of structural changes. Similarly, to the study by (Sakoulis and Zivot, 2001) the study utilises the five G7 countries for the period 1976 to 1999. Results show that when taking into account the effects of structural changes contrary to the first approach, the forward unbiased hypothesis is less biased. In other words, the failure of the forward hypothesis is reduced significantly.

Sakoulis, Zivot and Choi (2010) analyses the forward puzzle by modeling the forward discount as an AR (1) process and allowing for multiple structural breaks such as monetary shocks. Using both the stochastic multiple breaks model and Monte Carlo simulation; results were similar to those found by Choi and Zivot (2007).

Hatemi and Roca (2012) test the forward unbiased hypothesis in the presence of two structural changes namely the September 11 terrorist attack on the US and the 2003 Iraqi invasion. Using cointegration test to allow for multiple structural breaks for the Australian, Japan and European currency for the period January 1999 to December 2006, results indicate that the forward unbiased hypothesis does hold. These authors contend that for this hypothesis to hold it is crucial to take into account the effect of structural changes.

Zhao, de Haan, Scholtens and Yang (2013) investigates the relationship between Chinese future spot rate and the forward discount rate in the presence of structural changes such as the financial crisis. The study uses daily exchange rates, cointegration test and results indicate that the hypothesis holds in spring 2009 which is the period that countries where dealing and trying to overcome the financial crisis turmoil and the Chinese authorities returned to fixing its exchange rate to the US dollar.

Ho and Mo (2016) tests if the persistent changes in structural breaks or model misspecification contributes to the failure of UFRH. The paper utilises an autoregressive model on five major countries' currencies spanning from 1999 to 2012. The outcome of the study supports that multiple structural breaks is one of the sources driving the failure of UFRH, however imposing lag structure on the model does not reduce the persistent failure of UFRH.

Oh and Lee (2017) examines the unbiased forward hypothesis in the presence of multiple unknown structural changes in major currencies by utilising the Lagrange multiplier (LM) cointegration test and Monte Carlo simulations. The results show that when the impact of structural changes is considered and taken into account the forward unbiased hypothesis holds.

2.3 Systematic errors

Some authors have ascribed the failure of the forward unbiased hypothesis to the theory of systematic errors made by market participant. Studies that ascribed to this theory generally contend that when investors make use of available information when forming expectations on the movement and direction of the future spot, they expectations are not rational and usually biased therefore they make systematic prediction errors.

Lewis (1989) investigates the forward unbiased hypothesis in United States for the period 1980, which was characterised as a period which the market was still learning and adapting to the new process of money. Results show that the forward unbiased hypothesis did not become less biased over time, despite investors revising beliefs and learning about the market. This implies that rational expectation is not the only explanation for the failure of this hypothesis, but rather anticipation of future policy changes and risk premium are factors that should also be considered.

Aggarwal and Zong (2008) analyses the relation between spot and forward exchange rate for nine major currencies. This study finds that market participants in all nine countries forward exchange rate reacted slowly to new information and were pessimistic when forming expectations on the magnitude and direction of the future spot rate. These results indicate that the assumption of rational expectations is inconsistent with investors' behavior and does not hold when investors form their expectations.

Chakraborty (2009) argues that market participants do not have perfect knowledge about the forward exchange market and are not rational agents, therefore make systematic errors when predicting future spot exchange rate. Moreover, instead of being rational agents, market participant are not and use the learning and adoptive method when forming expectations. In other words, although new information is incorporated and fully reflected in the market, market participants do not possess all this information and as a result the assumption of rational expectation and the unbiased forward hypothesis does not hold.

Burnside, Han, Hirshleifer and Wang (2011) attribute the failure of the forward unbiased hypothesis to overconfidence by investors. When forming expectations on the future spot rate, Investors overact when making use of information available on future inflation rate and as results the forward exchange overshoots contrary to the spot rate. For instance when investors observe high inflation rates, they overreact and as a result "the consequent rise in the forward premium predicts a subsequent downward correction of the spot rate". Other studies that have ascribed to this explanation include Chakraborty and Haynes (2005), Darvas (2009) and Moon and Velasco (2011).

2.4 Risk Premium

Studies that focused on the risk premium approach argue that the assumption of risk neutrality fails to take cognizance of the reality that investors are risk averse and that when testing the UFRH, the risk premium should be embedded in the forward rates. In other words contended that investors are not risk neutral and want to be compensated for the risk they take.

Fama (1984) test the UFRH in nine major currencies for the period 31 August 1973 to 10 December 1982 by analysing the composition of the forward exchange rate; variations in the expected future spot rate and time varying premium. The author shows that variations that existed in the forward rates is attributed to variations in the forward premium. In addition, that the expected future spot rate is negatively correlated to the forward rate.

Contrary to the above studies, Frankel and Poonawala (2010) extended their study to 14 emerging and 21 developed economies for the period 1996 to 2004 by stating that although an extensive literature on the UFRH has been conducted, these studies primarily focus on advanced economies and major currencies. Therefore, this study aims to fill this gap. By comparing developed and developing countries results suggest that the failure of the UFRH is more pronounced in developed economies than it was for developing countries. These results contradict the risk premium theory given that developing countries' currencies are more volatile, suggesting that the failure of UFRH cannot entirely be driven by a risk premium.

Lucey and Loring (2012) extended the study by Frankel and Poonawala (2010), to the period covered from 1996 to 2011 by using an updated composition of currency sourced from the World Bank. Contrary to Frankel and Poonawala (2010) these authors find that in the extended period the failure of UFRH is more pronounced for developing economies. Further explaining that the results obtained in the previous study could be attributed to the time period examined.

Wang and Bidarkota (2012) investigate the relationship between the Pound, Yen and Euro's monthly spot and forward exchange rate in the presence of a time varying risk premium. The study employs a signal plus noise model and finds that the hypothesis fails to hold. Results show the presence of risk premium in all three currencies. This indicate the existence of a time varying risk premium given the assumptions of the forward hypothesis such as rational expectation.

There is enormous theoretical and empirical work on the UFRH. The above literature has looked at different aspects that could explain the contradicting results observed when examining the UFRH; model misspecification, structural breaks and risk premium. Literature that has focused on a nonlinear approach is growing, however there is currently no study that compares developed and developing countries results by applying a nonlinear smooth error correction model. The aim of this study is to fill this gap.

3. Methodology

3.1 Conditions for UFRH

It is important to note that the UFRH is derived from the combination of the covered interest parity (CIP) and the uncovered interest parity (UIP). The CIP states that interest rate differentials between two countries should be equal to the forward premium. The parity holds that forward contracts are used to hedge against exchange rate volatility (Madura, 2011). This parity condition can be specified as follows:

$$i_{t,t+k} - i^*_{t,t+k} = f_{t,t+k} - s_t \quad (1)$$

Where $i_{t,t+k}$ *and* $i^*_{t,t+k}$ represent the domestic and foreign interest rate at time t that would prevail at time t+k respectively, s_t is the spot exchange rate prevailing at time t and $f_{t,t+k}$ is the forward exchange rate at time t that would prevail at time t+k.

The uncovered interest rate parity does not hedge against exchange rate volatility and holds that interest rate differential between two countries should be equal to the expected change in spot exchange rate. This parity condition can be specified as follows;

$$E(s_{t+k} - s_t) = i_{t,t+k} - i^*_{t,t+k} \qquad (2)$$

$E(s_{t+k} - s_t)$ is the expected change in the spot exchange rate. Combining equation 1 and 2 one can deduce that:

$$E(s_{t+k} - s_t) = f_{t,t+k} \qquad (3)$$

Equation 3 provides the condition for the UFRH, which states that the forward exchange rate should be an unbiased estimator of the future spot exchange rate when both risk neutrality and rational expectation assumptions hold.

The specification of the econometric model of the UFRH is expressed as:

$$\Delta s_{t+k} = \alpha + \beta F_t + \varepsilon_t \qquad (4)$$

Δs_{t+k} represent the change in spot exchange rate, (βF_t) is the forward rate and ε_t is error term that is independently identically distributed with mean zero and variance σ^2. The null hypothesis for the UFRH is the restriction $\alpha = 0$ and $\beta = 1$.

3.2 Error correction model

When analysing time series data, macroeconomic variables are often trended and therefore are not only nonstationary but rather linked and move together in the long run. This concept is referred to as cointegration and was initially introduced by Engle and granger (1987), together with the concept of error correction models (Asteriou and Hall, 2007). The idea behind this is that when two variables that moves together in long run deviate from their equilibrium level, there are market forces that occur and an adjustment process takes place to prevent the errors from persisting and becoming larger (Error correction).

The extension of cointegration has been highly investigated and been applied to nonlinear models (Kılıç, 2011). Moreover the application of cointegration in the context of nonlinear adjustment has taken two main directions. The one direction focused on applying the standard linear cointegration model when testing nonlinear adjustment towards equilibrium. Many studies have relied on this direction and this includes research conducted by (Hansen and Seo, 2002 and Seo, 2004).

The second direction applied nonlinear cointegration model when examining and modelling nonlinear adjustment. Literature that took this direction includes studies by (Park and Phillips 1999 and Saikkonen and Choi 2004). Following from the two main direction of modelling and analysing cointegration, this study follows the first direction that applies a linear cointegration model, however uses a linearity test to confirm if the cointegration found is linear or nonlinear.

If there exist a long run relationship between the two rates, the study will investigate if the spot deviations from the forward exchange rate that occur in the short run persist or are corrected in the long run through market forces such as when arbitrageurs enter the exchange market to take advantage of those deviations. These will give insight on whether previous studies have rejected the UFRH on the basis of assuming there is no long run relation between the two rates and on whether these deviations cannot be corrected in the long run. Moreover as stated in the above literature the existence of a nonlinear relation between spot and forward exchange rate is plausible for the UFRH model. Therefore to investigate this possibility and a nonlinear adjustment process it is crucial to use a nonlinear error correction model.

3.3 Smooth transition error correction model

Nonlinear models have been very useful in explaining economic variables whose behaviour can be explained by the state of the world and have been applied in several literatures. Theories of exchange rate such as purchasing power parity theory, UIP and UFRH have become popular for using nonlinear models.

The most popular nonlinear model has been the smooth transition model (STR), where the adjustment process is gradual or smooth rather than a sharp switch. This process is consistent with how exchange rates changes over time. The model can be specified as follows:

$$\Delta s_{t+1} = [\alpha_1 + \beta_1(f_t - s_t)] + [\alpha_2 + \beta_2(f_t - s_t)]\mathrm{F}(\delta_t, \gamma, \rho) + \varepsilon_t \quad (5)$$

From the above equation G(.) represents bounded transition function which "determines the degree of reversion" to the UFRH condition, where δ_t in the transition function is the transition variable which can take either two forms; stationarity or time trend, γ is the transition parameter which determines how quickly the transition variable moves from one regime to the next and ρ represents the threshold parameter which determines the location in which the transition variable would be in. The transition function is assumed to be bounded between zero and one G(.)=0 and G(.)=1

The specification of the model also nests the linear relationship between variables by becoming a linear regression when the transition variable $\gamma = 0$ (Li, Ghoshray and Morley, 2013). Moreover in the standard use of a nonlinear model, the smooth transition model will be applied in the error correction model context.

The error correction model can be stated as follows:

$$\Delta s_{t+k} = a + b\Delta s_{(t+k)-1} + c\Delta F_{t-1} + \alpha(s_{t+k} - \beta F_t)_{t-1} \quad (6)$$

The parameter $s_{t+k} - \beta F_t$ is a representation the error correction term obtained from the cointegration between the spot and lag forward rate.

From the extension of the STR regression (See Equation 5) and the ECM as represented in Equation 6. The smooth transition error correction model for the UFRH can be specified as follows:

$$\Delta s_{t+1} = a_1 + b_1\Delta s_{(t+k)-1} + c_1\Delta F_{t-1} + \alpha_1(s_{t+k} - \beta F_t)_{t-1} + (a_2 + b_2\Delta s_{(t+k)-1} + c_2\Delta F_{t-1}\, \alpha_2(s_{t+k} - \beta F_t)_{t-1})G(\delta_t, \gamma, \rho) + \varepsilon_t \quad (7)$$

3.4 Logistic smooth transition regression

The STECM model as represented in equation 7 is a regime switching model bounded between 0 and 1 and can take the form of either a logistic STR (LSTR) or exponential STR (ESTR). However, following the procedure applied by (Bonga-Bonga, 2009) the transition variable in this study would either take the form of a LSTR1 or LSTR2 (an alternative form of LSTR2 is the ESTR).

The general logistic transition function is specified as follows;

$$F(\delta_{t,} \gamma, c) = [(1 + \exp\left\{-\gamma \prod_{k=1}^{k} (\delta_t - c_k)\}\right)]^{-1} \quad (8)$$

Whereas if the variable K=1 the logistic function represents an LSTR1 and K=2 represents the LSTR2. Lütkepohl and Krätzig (2004) distinguished the two by explaining that in the LSTR1 the transition variable moves between two extreme regimes; for instance between extremely large and small values, whereas the transition variable in LSTR2 moves between two identical regimes and the middle regime is the one that is different.

The LSTR1 model is more appropriate for modelling asymmetric behaviour whereby the process behaves differently depending on the two extreme regimes and the LSTR2 whereby the process behaves in the same manner in the two identical regimes, whether it is characterized by large or small values and behaves differently only in the middle regime.

3.5 Linearity test

When applying the STECM model, it is crucial to first determine whether a linear model is appropriate in modelling the relationship between the two variables and determine potential transition variables (Teräsvirta, 1994). This study makes use of an autoregressive model as an adequate linear model. Following the rejection of a linear model by a linearity test, then an appropriate STECM model; LSTR1 or LSTR2 is selected with the appropriate transition variable. The lagged forward premium is used as the transition variable for reasons stated in the above sections.

The auxiliary regression can be specified as follows:

$$s_{t+k} - s_t = \beta_0' \varphi_t + \sum_{i=1}^{3} \beta_i' \, \varphi' \rho_t^i + \varepsilon_t \tag{9}$$

Where β_0' and β_i' respectively represent the coefficient matrices. Teräsvirta (1994) specified the null and alternative hypothesis for testing nonlinearity and selecting an appropriate STR model as follows:

$$H_0: \beta_1 = \beta_2 = \beta_3 = 0 \tag{10}$$

$$H_0^4: \beta_3 = 0 \tag{11}$$

$$H_0^3: \beta_2 = 0 | \beta_3 = 0 \tag{12}$$

$$H_0^2: \beta_1 = 0 | \beta_2 = \beta_3 = 0 \tag{13}$$

Equation 8 represents the null hypothesis: the adjustment process is linear. If the null hypothesis is rejected alternative hypothesis represented by equation 11 to 12 are used to select an appropriate nonlinear STECM model. The LSTR2 model is used when equation 12 has the strongest rejection compared to other hypothesis whereas the LSTR1 model is selected when equation 12 does not yield the strongest rejection.

A nonlinear optimization process is used when estimating the parameters of the STR model. The process follows a four step procedure; operating the Gridsearch, testing restrictions, testing misspecifications in the STR model and a graphic analysis. The operating Gridsearch requires the transition variable to be determined first and chooses between LSTR1 and LSTR2 model. The Gridsearch is used to find initial values for the estimation of the STR model through creating either a linear grid in the threshold parameter or a log linear grid in the speed of adjustment parameter. Three setting restrictions can be used when estimating the STR model, for instance theta=0 implying parameter will be constant. The third step including diagnostic test for the STR model such as no error autocorrelation test. This is tests are used to test the quality of the estimated model used. Finally, a graphic analysis can be used to visually detect problems that can arise from the residuals (Krätzig, 2005)

4. **Data, estimation and discussion of results**

4.1 Data description

It is important to note that the aim of this paper consists in assessing whether the UFRH holds and estimate how fast any arbitrage opportunity can close in the forward market for selected emerging and developed economies. As stated earlier, the approach followed in this study is threefold; firstly, the study assesses whether there is a cointegration between spot and lag forward exchange rates, secondly test whether there is linear or nonlinear relationship between the two exchange rates and lastly, estimate the STECM in case the nonlinear relationship is found between the two rates. The last step is crucial as it informs how fast arbitrage opportunity closes for different maturity of the forward rates and in different locations.

The study follows Li, Ghoshray and Morley (2013) in selecting developed and emerging economies. Thus, the three developed economies, Germany, British and Japan are selected because of the vital role these currencies play in the forward exchange rate market. Russia, China and South Africa are selected on the basis of being members of BRICS as these countries are considered major emerging economies. The dataset consists of three months, six months and twelve months quarterly spot exchange rate and forward exchange rate covering the period 1998 to 2018. All spot exchange rate and forward exchange rate are expressed as the domestic currency against the US dollar. The data set was collected from Thomson Reuters. All spot and forward exchange rate are transformed into logarithm form.

4.2 Estimation, results and interpretation

In order to assess whether UFRH holds in a linear form, the paper tests the existence of the long run relationship (cointegration) between the spot and forward rate by making use of the Johansen cointegration test. As the first step in Johansen cointegration test is to conduct the unit root test. Table 1 to 6, reports results of the unit root test of all series tested using the augmented dickey fuller (ADF). The test results obtained suggest that all spot and forward exchange rates for all countries contain a unit root at a 5% significant level. The first differences of the series are stationary, which confirm that all series are

I(1). Furthermore, the Dicker Fuller GLS and Phillips Perron test were conducted and results validated results obtained from the ADF test (See appendix)

Table 1: unit root test for different series: ADF test for Germany

Variables	Level	First difference	Order of Integration
s_t	-1.455190	-7.562904**	I (1)
f_{t+3}	-1.472374	-7.588480**	I (1)
f_{t+6}	-1.460302	-7.588164**	I (1)
f_{t+12}	-1.431653	-7.533027**	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 2: unit root test for different series: ADF test for Japan

Variables	Level	First difference	Order of Integration
s_t	-2.105481	-8.715508**	I (1)
f_{t+3}	-2.120547	-8.718963**	I (1)
f_{t+6}	-2.127057	-8.676123**	I (1)
f_{t+12}	-2.138920	-8.600778**	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 3: unit root test for different series: ADF test for British

Variables	Level	First difference	Order of Integration
s_t	-4.060027	-7.494088**	I (1)
f_{t+3}	-4.020093	-7.689665**	I (1)
f_{t+6}	-3.989429	-7.766941**	I (1)
f_{t+12}	-3.948121	-7.939278**	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 4: unit root test for different series: ADF test for South Africa

Variables	Level	First difference	Order of Integration
s_t	-1.637967	-8.913484**	I (1)
f_{t+3}	-1.648528	-9.002071**	I (1)
f_{t+6}	-1.656044	-9.046084**	I (1)
f_{t+12}	-1.677730	-9.113204**	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 5: unit root test for different series: ADF test for Russia

Variables	Level	First difference	Order of Integration
s_t	-1.888436	-7.729185**	I (1)
f_{t+3}	-1.950791	-7.526366**	I (1)
f_{t+6}	-2.002915	-7.380638**	I (1)
f_{t+12}	-2.006991	-7.101201**	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 6: unit root test for different series: ADF test for China

Variables	Level	First difference	Order of Integration
s_t	-0.652312	-5.918388**	I (1)
f_{t+3}	-2.700386	-4.105580**	I (1)
f_{t+6}	-2.653644	-4.378556**	I (1)
f_{t+12}	-2.564333	-4.960775**	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

The Johansen cointegration test is reported in tables 7 and 8. The null hypothesis is that r=0: no cointegration and alternative hypothesis r=1: at most there exist one cointegration. The results of the trace test of cointegration reported in table 7 show that for the null hypothesis r=1 (one cointegrating relationship) is not rejected for all countries at a 5% significant level with the exception of Japan.

Results of the maximum eigenvalue test reported in table 8 similarly reject the null hypothesis of no cointegration (r=0) at a 5% significant level for all countries with the exception of Japan. Therefore, these results suggest the presence of a long run relationship between three month, six month and twelve months forward rates and spot rate for Russia, South Africa, China, Germany and British.

Table 7: Test of Johansen cointegration: Trace test

Countries	Hypothesis	3month	6month	12month	Critical value
Germany	r=0	17.05246	17.65192	15.77196	15.49471
	r=1	3.576146	3.662033	2.608418	3.841466
Japan	r=0	7.310020	6.553955	7.003707	15.49471
	r=1	1.806493	2.116667	2.367851	3.841466
British	r=0	26.86382	27.02747	22.26937	15.49471
	r=1	9.124672	9.596290	8.855718	3.841466
South Africa	r=0	18.25561	19.41487	16.94417	15.49471
	r=1	2.981583	3.101707	2.510370	3.841466
Russia	r=0	17.78642	17.99791	18.05630	15.49471
	r=1	1.557230	1.638149	1.676108	3.841466
China	r=0	19.54627	21.04293	21.33222	15.49471
	r=1	6.227544	6.079627	5.931607	3.841466

Table 8: Test of Johansen cointegration: Maximum eigenvalue test

Countries	Null hypothesis	3month	6month	12month	Critical value
Germany	r=0	13.47632	13.98989	13.16354	14.26460
	r=1	3.576146	3.662033	2.608418	3.841466
Japan	r=0	5.503527	4.437288	4.635856	14.26460
	r=1	1.806493	2.116667	2.367851	3.841466
British	r=0	17.73915	17.43118	17.24749	14.26460
	r=1	9.124672	9.596290	8.855718	3.841466
South Africa	r=0	15.27403	16.31316	14.43380	14.26460
	r=1	2.981583	3.101707	2.510370	3.841466
Russia	r=0	16.22919	16.35976	16.38019	14.26460
	r=1	1.557230	1.638149	1.676108	3.841466
China	r=0	14.31873	14.96330	15.40061	14.26460
	r=1	6.227544	6.079627	5.931607	3.841466

In addition, results of the Engle Granger approach test are reported in table 9. We test the whether the residuals of the relationship between spot and forward rates are stationary. The results reported in Table 9 validate those of the Johansen test.

Table 9: Test of Engle Granger approach

Countries	Null Hypothesis	3month	6month	12month

Germany	Residuals are stationary	-2.752256**	-2.883840**	-1.479934**
Japan	Residuals are stationary	-3.760439	-3.882103	-4.564058
British	Residuals are stationary	-2.845193**	-2.373486**	-2.835707**
South Africa	Residuals are stationary	-2.458752**	-2.472466**	-2.477565**
Russia	Residuals are stationary	-2.803010**	-2.384393**	--2.841022**
China	Residuals are stationary	-2.873771**	-2.643599**	-2.441702**

** indicate rejection of the null hypothesis of no cointegration at a 5% significant level

Having satisfied the cointegration test, the next step would be to determine whether there is a nonlinear relationship between the two exchange rates. Table 10, 11 and 12 reports p values estimations of the linearity test conducted for 3 months, 6 months and 12 months respectably. Based on the aim of this study three potential transition variables were selected namely; the forward premium, one lagged forward premium and two lagged forward premium.

Table 10: Linearity test 3_Months

	Transition variable	H_0	H_0^2	H_0^3	H_0^4	Model
Euro	Lagged forward premium	2.1872e-04	1.0052e-05	2.8088e-02	4.9055e-01	LSTR1
British	Lagged forward premium	2.7909e-06	1.0113e-02	3.0418e-06	6.0467e-01	LSTR1
South Africa	Lagged forward premium	3.2875e-04	3.3277e-03	2.8504e-02	3.8646e-02	LSTR1
Russia	Lagged forward premium	1.0090e-06	5.3014e-05	7.0355e-03	7.2191e-03	LSTR1
China	Lagged forward premium		3.4044e-01	5.3480e-03		Linear

Table 11: Linearity test 6_Month

	Transition variable	H_0	H_0^2	H_0^3	H_0^4	Model
Euro	Lagged forward premium	2.3201e-04	1.0637e-05	3.0956e-02	4.7418e-01	LSTR1
British	Lagged forward premium	1.3715e-06	7.0250e-03	1.9543e-06	6.1845e-01	LSTR1
South Africa	Lagged forward premium	8.6974e-04	3.7995e-03	1.3529e-01	2.3411e-02	LSTR1
Russia	Lagged forward premium	1.9210e-07	4.5670e-05	1.4214e-02	8.9161e-04	LSTR1
China	Lagged forward premium	5.1077e-02	9.6170e-02	2.3894e-02	9.1717e-01	Linear

Table 12: Linearity test 12_Months

	Transition variable	H_0	H_0^2	H_0^3	H_0^4	Model
Euro	Lagged forward premium	3.2105e-04	1.1512e-05	3.9302e-02	4.9418e-01	LSTR1
British	Lagged forward premium	4.6475e-07	3.6244e-03	1.0762e-06	6.8829e-01	LSTR1

South Africa	Lagged forward premium	1.2438e-02	5.5730e-03	1.1907e-01	2.7432e-01	LSTR1
Russia	Lagged forward premium	2.8546e-08	1.9446e-05	1.7785e-02	2.0134e-04	LSTR1
China	Lagged forward premium	2.6804e-11	2.4775e-03	6.9739e-11	4.0663e-01	Linear

Each transition variable was tested and results indicated that the one lagged forward premium for all countries with the exception of China had the smallest p value (strongest test rejection). This implies that the one lagged variable out of the three transition variable is the chosen transition variable. Moreover, results for China for all three transition variables were linear. Therefore, results for China confirms the results found from the cointegration test, which indicated that there is a linear relationship between spot and forward exchange rate.

Following from choosing the one lagged forward premium as the transition variable and testing for linearity, the decision between LSTR1 and LSTR2 has to be made on the basis of the test sequences of equations 13 to 16. The linearity test suggests that LSTR1 model is appropriate for all the countries for all periods.

The results of the STECM estimation are reported in table 13 through table 16 for all the sample countries. The focus of this study will be on the coefficients α_1 and α_2 which show the speed of adjustment according to the different regimes. it is important to note that these regimes are determined by the threshold coefficients. Moreover, that results reported represented in terms of the following equation

$$\Delta s_{t+k} = a_1 + b_1 \Delta s_{(t+k)-1} + c_1 \Delta F_{t-1} + \alpha_1 (s_{t+k} - \beta F_t)_{t-1} + (a_2 + b_2 \Delta s_{(t+k)-1} + c_2 \Delta F_{t-1} + \alpha_2 (s_{t+k} - \beta F_t)_{t-1}) G(\delta_t, \gamma, \rho) + \varepsilon_t \quad (10)$$

Table 13: STECM estimation for Germany

	Variable	3months (K=3)	6 Months (K=6)	12 Months (K=12)
		Coefficient	Coefficient	Coefficient
Germany	a_1	-0.7522184**	-0.34997112 **	0.4454395**
	b_1	0.9540423 **	0.72701851 **	-1.3130915
	c_1	1.2335472 **	1.00392110	-1.0160377
	α_1	-0.159344 **	-0.41288163	0.0417292 **
	a_2	13.197414 **	3.83522093	-0.5339461
	b_2	5.6857490 **	0.13864530 **	2.9845008
	c_2	-1.5291381 **	-2.03026981	2.7845074
	α_2	-0.0849804**	-0.46008491 **	1.0371457 **
	Gamma	0.6432922 **	1.15228226 **	4.1447252
	C	-0.1245345 **	-0.10870166**	1.9350170**

** indicate coefficient is statistically significant at a 5% significant level

Table 13 reports estimation results of the maximum likelihood estimation of the STECM for Germany between the spot rate and each of the three forward rates (3-month ,6-month and 12-month forward rate). The results indicate that for the 3-month forward rate, the threshold (C) is 0.1245. This implies that the speed of adjustment to correct any disequilibrium between the forward and spot rate varies whether the forward premium (difference between the spot and forward) is below or above 12.45%. For example, the results reported in Table 13 show that if C is below 12.45%, which implies that G is close to zero the speed of adjustment to equilibrium is statistically significant at. 15.93%. However, if the forward premium is above 12.45%, i.e. G is close to unity, the speed of adjustment is 24.22% $(\alpha_1 + \alpha_2)$. This implies that the 3-month forward market becomes highly active, especially with arbitrageurs, when there is a possibility of higher profit (forward premium), consequently the equilibrium readjusts at a very high speed, compared to the case when profit is below 12.45%.

With regard to the 6-month forward market, the results obtained in table 13 indicate coefficients that are correctly negatively assigned and statistically significant. In comparison to the 3-month findings, results of the 6-month period show the threshold for forward premium at of 10.87%, lower than the 3-month forward market. However, given that α_1 is not statistically significant (not different to zero), these results imply that adjustment occurs only if the forward premium is above 10.87% with the speed of adjustment at 46%. this reality show that arbitrageurs often participate in the forward market if there is a possibility of a high profit that could compensate any transaction cost. Results of the 12-month period for Germany showed that the sum of coefficient estimations $\alpha_1 + \alpha_2$ is greater than unity. Moreover, results of the coefficient estimations are positive which is inconsistent with the error correction model specification. These results indicate that no adjustment process takes place when deviations occur. this may indicate possibility of inactivity in the 'long-term' forward market.

Table 14: STECM estimation for British

	Variable	3months (K=3)	6 Months (K=6)	12 Months (K=12)
		Coefficient	Coefficient	Coefficient
British	a_1	4.03479908 **	3.681**	3.794275
	b_1	-5.19805179 **	-4.443	-3.157731**
	c_1	5.53007537 **	4.660	3.427017
	α_1	-0.37815453 **	-0.361**	-0.357899
	a_2	-4.18402056**	-3.565 **	-3.610995
	b_2	-19.0995994 **	-10.961**	-4.677328**
	c_2	18.8090104**	10.739	4.402916
	α_2	-0.48936350**	-0.507 **	-0.507487
	Gamma	0.7849178**	3.399 **	4.003944
	C	-0.6432922**	-4.961**	-4.936129

** indicate coefficient is statistically significant at a 5% significant level

The STECM estimation for British as shown in table14 for the 3-month period suggest that the coefficient of α_1 and α_2 are negative, statistically significant and the sum of them is less than unity. Results indicate that for the 3-month forward rate, the threshold (C) is 0.6433. This implies that the speed of adjustment to correct any disequilibrium between the forward and spot rate varies whether the forward premium is below or above 64.33%. For example, in a regime where the transition function is less than the threshold (C), G=0, the speed of adjustment to equilibrium is statistically significant at 38%, whereas in the regime where the transition function is more than the threshold parameter (c), (G=1), 85% of the disequilibrium is corrected in the first three months.

The maximum likelihood results of STECM estimation reports of the 6-month period shows that no adjustment process takes place. Results show that the sum of the coefficient estimation $\alpha_1 + \alpha_2$ is greater than unity. The implication of these results is that when arbitrage opportunities occur, there is no adjustment process that takes place because market participants are not willing to trade on these deviations

The results of the 12-month nonlinear STECM model estimation for British. The findings suggest that coefficient of α_1 and α_2 are correctly assigned however these results are statistically insignificant at a 5% significant level. Contrary to the results found in the 3-month period the speed of adjustment for the 12- month period is high, indicating that when deviations occur, market participants react quickly and trade on the deviations making riskless profit and these deviations quickly close as the spot rate adjust to its long run equilibrium.

Table 15: STECM estimation for South Africa

	Variable	3months (K=3)	6 Months (K=6)	12 Months (K=12)
		Coefficient	Coefficient	Coefficient
South Africa	a_1	-1.129143316**	1.490499 **	-170.647160
	b_1	-0.133565514	-2.255324 **	-1.732014
	c_1	-0.085173765 **	2.224417	1.392396
	α_1	-0.205749813**	-0.161445 **	-1.944855
	a_2	6.663429359 **	18.491508**	363.005628
	b_2	-0.272945341**	10.029773 **	3.012418
	c_2	0.330109052	-9.653235 **	-2.174550**
	α_2	-0.104976577**	-1.387948 **	1.606632
	Gamma	2.057371087 **	3.151382 **	0.031174
	C	-0.728151047**	-0.8728434 **	3.049080 **

** indicate coefficient is statistically significant at a 5% significant level

Estimation results of the maximum likelihood estimation of STECM for South Africa for the 3-month period show coefficient of α_1 and α_2 that are negative and statistically significant (see table 15). Results show negative coefficient slopes ($\alpha_1 + \alpha_2$) whose sum are less than unity which is consistent with the error correction model specification. This indicates that the spot and 3-month forward rates move together in the long run and that although deviations can occur in the short run when the spot rate drifts away from the forward rate, there exist market forces that will ensure that these deviations do not persist.

The results indicate that for the 3-month forward rate, the threshold (C) is 0.7282. This implies that the speed of adjustment to correct any disequilibrium between the forward and spot rate varies whether the forward premium is below or above 72.82%. For instance, in the regime where the transition function is less than the threshold parameter (C) (G=0), the adjustment parameter for South Africa is 21%.

While in the regime where the transition function is more than the threshold parameter (C), (G=1), close to 31% of the disequilibrium are corrected in the first three months. the relatively small slope parameter (2.057) confirm that the transition between the two regimes are smooth.

The coefficient estimation ($\alpha_1 + \alpha_2$) of the 6 and 12-month STECM estimation are similar to that of the 12-month results for Germany (See table 15), with the sum of the coefficients greater than unity and statistically insignificant at 5% level for the12-month period. The implication of these results is that when arbitrage opportunities occur, there is no adjustment process that takes place. The no adjustment process can be attributed to higher transaction cost, implying that deviations in the medium run and long run for South Africa occurs and persist because market participants are not willing to trade on these deviations. The speed of adjustment for the 6-month period is high which shows faster transition of the forward premium from one regime to the other, however at a 5% significance level this result is statistically insignificant.

Table 16: STECM estimation for Russia

	Variable	3months (K=3)	6 Months (K=6)	12 Months (K=12)
		Coefficient	Coefficient	Coefficient
Russia	a_1	0.48558335**	0.59089102 **	0.58007328**
	b_1	1.95733725 **	1.49025370 **	0.92859508
	c_1	-1.77249788 **	-1.3324181	-0.74461674**
	α_1	-0.05260604 **	0.04220588 **	-0.04905122**
	a_2	35.18545348**	4.72640980 **	40.34312482
	b_2	7.70187974	-5.02600543 **	-2.90607394 **
	c_2	8.72573624	6.22181610 **	3.97229232
	α_2	-0.11997757 **	-0.64814458**	-0.05406852 **
	Gamma	4.95001022 **	3.25397691**	4.412557871**
	C	-7.32810814**	-0.68379805 **	-0.64980467**

** indicate coefficient is statistically significant at a 5% significant level

Russia estimation results of the maximum likelihood estimation of the 3-month STECM model have coefficients slopes that are inconsistent with the error correction theory (See table 16). This implies that there is no adjustment process that takes place in Russia when the spot rate deviates from the 3-month forward rate, indicating that deviations occur and persists.

Findings for the 6-month results indicate that after maximising the likelihood of the STECM estimation, an adjustment process does take place. The results indicate that for the 6-month forward rate, the threshold (C) is 0.6837. This implies that the speed of adjustment to correct any disequilibrium between the forward and spot rate varies whether the forward premium is below or above 68.37%. The speed of adjustments are close 4.2% and 65% at lower and higher regimes, respectively.

Results of the 12-month STECM estimation are similar to the 6-month period, they show that when deviations occur, they do not persist but rather that an adjustment process takes place. The coefficient estimation ($\alpha_1 \text{and } \alpha_2$) are statically significant, correctly negatively assigned and the sum of these coefficients is less than unity. In a regime where the transition function is less than the threshold parameter (c), (G is close to zero), 4% of disequilibrium is corrected whereas when the transition function is more than the threshold parameter (c), G is close to one, in contrast to the 6-month period findings, 9% reversion takes places in Russia. In comparison to the 6-month period the speed of adjustment for the 12-month period is faster. This shows that the forward premium moves quickly from one regime to other.

The commonality of these results, for emerging and developed economies, is that short-term forward markets, the 3-month forward markets, are more active for arbitrage opportunity. The busy activities in these markets are substantiate by the fact that correction to arbitrage are common with speed of adjustments that are statistically significant and of the right sign. Rapid adjustment towards equilibrium can occur when the benefits from the arbitrage opportunity is greater than the transaction cost for exchange market participants to trade on these deviations.

Moreover, the speed of adjustment is higher in the higher regime compared to lower regime. This is evident as arbitrageur participate in these markets if they expect a higher profit, above any transaction cost.

the noticeable difference between developed and emerging markets is that the threshold parameter, the forward premium, is often higher in emerging market compared to developed economies. this is expected given the level of risks in emerging market where market participants and arbitrageurs expect a higher profit that compensate for risk and transaction costs.

5. Conclusion

5.1 Introduction

This chapter's main focus is to summarise the findings obtained from assessing the UFRH in developed and emerging economies. Firstly, it will highlight what the study set out to do. Following from the rational and objective of the study, a brief summary of the findings will be outlined. Finally, it will show the limitations of the study and further recommendation on where further research can be conducted.

5.2 Rational and objective of the study

This study set out to assess whether the UFRH holds in its strong or weak form in selected developing and emerging economies. The study utilised two cointegration tests namely Engle-Granger and Johansen test after conducting stationarity test to analyse whether there exist a long run relationship between forward and future spot exchange rates in selected economies. To investigate whether the relationship is better specified by a linear or nonlinear model, linearity test was used. Moreover an STECM model was employed to uncover the band of arbitrage profit in the forward exchange market in developed and emerging economies and the speed to which arbitrage profits are precluded and equilibrium between spot and forward exchange rates

The rationale behind this study was to provide significant insight into how to make accurate predictions on the direction and magnitude of the future spot rate, given information on the forward exchange rate. Moreover, since the forward exchange rate market has a number of participants ranging from financial institutions, households, firms, central banks and nonfinancial institution, this study will benefit and inform forex participants on the implications the UFRH has on the economy, expected return and trading strategies.

The three main questions the study set out to answer were as follows:

1 Is there a long run relationship between spot exchange rate and forward exchange rates of different periods?
2 If present, when arbitrage opportunity occurs through deviations of the future spot rate from the forward rate, do they persist or are they corrected?
3 Is the speed of adjustment in developed economies faster than in developing economies?

5.3 Summary of results

The finding from the results obtained showed that the forward and future spot rate for all currencies were nonstationary when three stationarity test were employed. Furthermore, when examining whether there exist a long run relationship between the two variables, results obtained from the Engle-Granger and Johannsen test indicated that the forward and future spot rate for all countries were cointegrated. This implied that the two variables moved together in the long run and that there exist an equilibrium level where the forward rate equals the future spot rate.

Following from this test, an estimation of whether the relation between the future and forward exchange rate is linear or nonlinear was conducted by conducting a linearity test. Results showed a nonlinear adjustment for all countries with the exception of China when the lagged forward premium was used as a transition variable. Moreover, the decision using an LSTR1 and LSTR2 had to be made on the basis of the test sequences of equations 13 to 16. The linearity test suggested that LSTR1 model was appropriate for all the countries.

Moreover, when analysing whether the UFRH holds and speed of adjustment, the study focused the coefficient of $\alpha_1 \text{ and } \alpha_2$ which represented the speed of adjustment and the confirmation of the nonlinear adjustment between spot and lag forward in each of the country. Results obtained for the 3-month period showed that market participants in South Africa reacted faster than those in British. These results were indicated by the fast speed of adjustment coefficient in South Africa in comparison to that of British. However, the disequilibrium that was corrected in British in both regimes was higher than that in South Africa.

For the 6-month period results indicated that for Germany in comparison to Russia showed that the speed of adjustment was slow. These results indicated that when deviations occurred, market participants in the Russian exchange quickly traded on these deviations contrary to those Germany. Finally, for the 12-month period, results were only significant for Russia and the speed of adjustment in that period was faster than the 6-month period.

These results implied that the speed of adjustment both in the short, medium and long run in emerging economies occurred more rapidly in comparison to developed countries. However, disequilibrium that was corrected in developed countries was more than those in emerging countries all both periods. Moreover, that when arbitrage opportunities occurred, market participants in emerging countries reacted faster than those in developed countries. The adjustment process for South Africa and British only took place in the short run; Russia took place in both medium and long term and for Germany in the medium run. These results were consistent with the literature by Frankel and Poonawala (2010).

5.4 Limitations and recommendation

the study shows that due to high risk, the forward market in emerging markets lag behind those of developed economies and limit the possibility of arbitrage profits. many attributes such limitations to the lack of liquidity of currency markets and a number of risks recurrent to emerging markets. policy makers in emerging markets need to set right policy that can improve the liquidity of their forward markets as these markets are important for hedging and arbitrage opportunities.

we suggest for future studies that other nonlinear models such as Markov Switching Vector Error Correction models (MS-VECM) to identify the threshold parameters and speed of adjustment in the forward market.

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Appendix

Table 2.1: unit root test for different series: DF-GLS test for Germany

Variables	Level	First difference	Order of Integration
s_t	-1.356063	-7.613773**	I (1)
f_{t+3}	-1.366247	-7.637339**	I (1)
f_{t+6}	-1.361728	-7.636499**	I (1)
f_{t+12}	-1.343145	-7.580655 **	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 2.2: unit root test for different series: DF-GLS test for Japan

Variables	Level	First difference	Order of Integration
s_t	-1.284807	-1.977707 **	I (1)
f_{t+3}	-1.320550	-1.981249 **	I (1)
f_{t+6}	-1.350363	-1.966046 **	I (1)
f_{t+12}	-1.409231	-1.938428 **	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 2.3: unit root test for different series: DF-GLS test for British

Variables	Level	First difference	Order of Integration
s_t	-0.922229	-7.529949**	I (1)
f_{t+3}	-0.933199	-7.736945**	I (1)
f_{t+6}	-0.937174	-7.766885**	I (1)
f_{t+12}	-0.948217	-7.854175 **	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 2.4: unit root test for different series: DF-GLS test for South Africa

Variables	Level	First difference	Order of Integration
s_t	-0.343912	-1.265872 **	I (1)
f_{t+3}	-0.380655	-1.149179 **	I (1)
f_{t+6}	-0.408307	-1.084523 **	I (1)
f_{t+12}	-0.460265	-0.979943 **	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 2.5: unit root test for different series: DF-GLS test for Russia

Variables	Level	First difference	Order of Integration
s_t	-0.592425	-7.696659 **	I (1)
f_{t+3}	-0.598443	-7.552063 **	I (1)
f_{t+6}	-0.640886	-7.424344 **	I (1)
f_{t+12}	-0.634447	-7.148424 **	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 2.6: unit root test for different series: DF-GLS test for China

Variables	Level	First difference	Order of Integration
s_t	0.509616	-5.964618 **	I (1)
f_{t+3}	-0.371774	-4.141553**	I (1)
f_{t+6}	-0.452587	-4.440229**	I (1)
f_{t+12}	-0.644843	-4.805107**	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 3.1: unit root test for different series: Phillips- Perron test for Germany

Variables	Level	First difference	Order of Integration
s_t	-1.577425	-7.569184**	I (1)
f_{t+3}	-1.592884	-7.594396**	I (1)
f_{t+6}	-1.582294	-7.593630**	I (1)
f_{t+12}	-1.561747	-7.538213**	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 3.2: unit root test for different series: Phillips- Perron test for Japan

Variables	Level	First difference	Order of Integration
s_t	-2.109851	-8.716433 **	I (1)
f_{t+3}	-2.128326	-8.719813 **	I (1)
f_{t+6}	-2.144286	-8.676366 **	I (1)
f_{t+12}	-2.178218	-8.600659 **	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 3.3: unit root test for different series: Phillips- Perron test for British

Variables	Level	First difference	Order of Integration
s_t	-2.788494	-7.659741**	I (1)
f_{t+3}	-2.823785	-7.854178**	I (1)

f_{t+6}	-2.856485	-7.925929**	I (1)
f_{t+12}	-2.882744	-8.091730 **	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 3.4: unit root test for different series: Phillips- Perron test for South Africa

Variables	Level	First difference	Order of Integration
s_t	-1.695405	-8.911609 **	I (1)
f_{t+3}	-1.711153	-8.994610 **	I (1)
f_{t+6}	-1.744901	-9.034648 **	I (1)
f_{t+12}	-1.778722	-9.093748 **	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 3.5: unit root test for different series: Phillips- Perron test for Russia

Variables	Level	First difference	Order of Integration
s_t	-1.989273	-7.733412 **	I (1)
f_{t+3}	-2.170886	-7.536613 **	I (1)
f_{t+6}	-2.002915	-7.397492 **	I (1)
f_{t+12}	-2.304201	-7.127151**	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 3.6: unit root test for different series: Phillips- Perron test for China

Variables	Level	First difference	Order of Integration
s_t	-0.755264	-6.227187**	I (1)
f_{t+3}	-2.467326	-4.374466**	I (1)
f_{t+6}	-2.474617	-4.544518**	I (1)
f_{t+12}	-2.496007	-5.127685**	I (1)

** indicate rejection of the null hypothesis of unit root at a 5% significant level

Table 10: Linearity test 3_Months

	Transition variable	H_0	H_0^2	H_0^3	H_0^4	Model
Euro	Lagged forward premium	2.1872e-04	1.0052e-05	2.8088e-02	4.9055e-01	LSTR1

British	Lagged forward premium	2.7909e-06	1.0113e-02	3.0418e-06	6.0467e-01	LSTR1
South Africa	Lagged forward premium	3.2875e-04	3.3277e-03	2.8504e-02	3.8646e-02	LSTR1
Russia	Lagged forward premium	1.0090e-06	5.3014e-05	7.0355e-03	7.2191e-03	LSTR1
China	Lagged forward premium		3.4044e-01	5.3480e-03		Linear

Table 11: Linearity test 6_Month

	Transition variable	H_0	H_0^2	H_0^3	H_0^4	Model
Euro	Lagged forward premium	2.3201e-04	1.0637e-05	3.0956e-02	4.7418e-01	LSTR1
British	Lagged forward premium	1.3715e-06	7.0250e-03	1.9543e-06	6.1845e-01	LSTR1
South Africa	Lagged forward premium	8.6974e-04	3.7995e-03	1.3529e-01	2.3411e-02	LSTR1
Russia	Lagged forward premium	1.9210e-07	4.5670e-05	1.4214e-02	8.9161e-04	LSTR1
China	Lagged forward premium	5.1077e-02	9.6170e-02	2.3894e-02	9.1717e-01	Linear

Table 12: Linearity test 12_Months

	Transition variable	H_0	H_0^2	H_0^3	H_0^4	Model
Euro	Lagged forward premium	3.2105e-04	1.1512e-05	3.9302e-02	4.9418e-01	LSTR1

British	Lagged forward premium	4.6475e-07	3.6244e-03	1.0762e-06	6.8829e-01	LSTR1
South Africa	Lagged forward premium	1.2438e-02	5.5730e-03	1.1907e-01	2.7432e-01	LSTR1
Russia	Lagged forward premium	2.8546e-08	1.9446e-05	1.7785e-02	2.0134e-04	LSTR1
China	Lagged forward premium	2.6804e-11	2.4775e-03	6.9739e-11	4.0663e-01	Linear