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THE EFFICIENCY OF FOREIGN EXCHANGE MARKETS IN EMERGING ECONOMIES: EVIDENCE IN BRICS COUNTRIES

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This thesis investigates whether the foreign exchange markets are efficient in the emerging economies. The emerging economies include Brazil, China, India, Russia and South Africa. The motivation behind this research is to provide an insight to the investor whether it is a worthwhile decision to invest in the foreign exchange markets. In order to prove the efficiency of the foreign exchange markets, three hypotheses were tested – the uncovered interest rate parity (UIP) condition, the unbiased forward rate hypothesis (UFH)/rational expectations hypothesis (REH) and the efficiency market hypothesis (EMH).

The examination is performed using various econometric tools. These include the OLS, VAR, VECM and the Johansen cointegration test. The time-series data used for this research was obtained from the Thompson Reuters Datastream, the website of Federal Reserve Bank of St. Louis (FRED) and the website of the Organization for Economic Co-operation and Development (OECD). The time period for this research was from 31st March 2004 to 30th April 2018.

We find that the UIP condition does not hold for any of the BRICS countries. The forward rates are not the unbiased predictors of the spot rate for any of the BRICS countries. The spot and forward rates were cointegrated for the Brazilian real, the Chinese yuan and the Russian ruble. Whereas, the spot and forward rates were not cointegrated for the Indian rupee and the South African rand. The rate of depreciation and the forward rate premium for India and South Africa are cointegrated but the same for the Chinese yuan are not cointegrated.
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1 INTRODUCTION

1.1 Background and Motivation

The topic of market efficiency has been in the finance literature since the 1970’s. The efficiency of a market is acknowledged as a critical tool that has been used both in the private and the public sector. Sharpe (2007) states that the private sector uses it as a policy in risk management whereas the public sector uses it in central bank intervention.

It is an integral part of the objectives that any financial market is efficient and every country strives to achieve it. Fama (1970) states that a financial market is efficient when the available information is fully reflected in the prices of financial securities. This applies to the foreign exchange markets as well. If the empirical research shows that the foreign exchange markets are inefficient, this means that the investors are losing out on risk-based profit opportunities and agents can make strategies on how to capture them. Also, in inefficient markets, one can easily formulate the exchange rates as they outperform the forecasts in the present markets.

According to Fama (1970), a market is claimed to be efficient when the market prices capture the available information. Thus, any news or changes from the exogenous factors must be conveyed in the prices. If there is no knowledge about whether a particular foreign exchange market is efficient, then investors will have a difficult experience in the market. In the public sector, the policymakers would claim the inefficiency as a ‘market failure’. When a market fails, it means that the cost of the market failure will be borne by someone in terms of reduced form of output, higher rate of unemployment and/or higher prices.

On the other hand, if a market is termed as efficient, then investors can assume that all market prices are the best reflection of all the available information. The chances of outperforming the market will lower for agents and thus, making abnormal profits become difficult.
Sharpe (2007) observed the following characteristics of perfectly efficient markets. The characteristics are listed as follows:

1) Investor can earn normal profits on their investments.
2) Markets will be efficient only if there are enough players in the market who think the market is not efficient.
3) Investments that are publicly known cannot earn abnormal profits.
4) Professional agents should not outperform in choosing financial securities than the ordinary agents.
5) The future performance of the financial securities should not reflect the past performance.

This research focuses on the efficiency of the foreign exchange markets in the emerging economies. This study helps an interested investor to plan whether he/she would like to invest in the foreign exchange markets in the emerging economies, such as the BRICS. The intention behind studying about the emerging economies is that these economies are experiencing a transition phase from being developing countries to becoming developed ones (hence the word ‘emerging’ is used). A lot of political, social and economic changes are taking place in these economies. Therefore, this research is meant to examine the relevant changes occurring from the perspective of international finance.

1.2 Purposes of Research

The purpose of this research is to examine the efficiency of the foreign exchange (FX) rate markets of emerging economies. The motivation behind this research is to provide an insight to an interested investor whether it is a worthwhile decision to invest in the FX markets. The investor can decide whether he/she wants to invest in an efficient or an inefficient market (investing in an inefficient market can sometimes be beneficial for the investor if he/she has entered the arbitrage trade opportunity and made some positive returns). This research will conduct an econometric investigation of five emerging economies – Brazil, Russia, India, China and South Africa (also known as the BRICS countries). For testing the efficiency, three hypotheses are
tested. These are the UIP condition, the unbiased forward rate hypothesis/rational expectations hypothesis and the efficient market hypothesis.

1.3 Scope and Limitations

There are assumptions as well as setbacks in this research. The research was targeted towards the BRICS countries since these countries are the five of the largest emerging economies. Thus, they are assumed to be an accurate representation of all the other emerging economies and it is also assumed that the other emerging economies will exhibit similar behavior. Similar studies could have been performed for other developing countries to examine their behavior specifically. However, this is beyond the scope of this research due to lack of availability of data.

Next, we assume that the investors in the foreign exchange markets are risk neutral and rational. This may not always be consistent in the real world. Also, in order to give a more realistic model of the real world, we need to take the transaction costs into account in our study. Due to the lack of availability of the relevant data, it was not considered in the study. Similarly, the assumptions of absence of taxes when capital transfers are involved as well as the presence of perfect capital mobility is considered.

1.4 Main Findings

The research question of this study can be further broken down into three question in order to test the main hypothesis. Firstly, we find that the UIP condition does not hold for any of the BRICS countries. Moreover, we also find that the forward rates are not the unbiased predictors of the future spot rate for any of the BRICS countries.

As far as the cointegration tests of the spot and forward rates were concerned, we found that the rates are cointegrated for the Brazilian real, the Chinese yuan and the Russian ruble, whereas, the rates were not cointegrated for the Indian rupee and the South African rand.
We also examined the cointegration test for the rate of depreciation and the forward rate premium. We find that we cannot come to conclusion whether the variables of Brazil and Russia are cointegrated. The variables for India and South Africa are cointegrated and the same for the Chinese yuan are not cointegrated.

1.5 Road Map

The roadmap to this thesis proposal is as follows: Chapter 2 provides the relevant theoretical overview as well as the previous empirical evidence. Chapter 3 discusses the research problem, the sources of the data and the research methodology in detail. Chapter 4 explains the empirical results that are obtained from the tests. Chapter 5 provides the conclusion for the study and also discusses the limitation of this thesis. The references and the appendices are listed thereafter.
2 THEORETICAL FRAMEWORK

This chapter gives a theoretical overview that will help the reader to appreciate the research and the chapter also discusses the previous empirical evidence. Table 1 lists the common notations used in this chapter of the thesis.

Table 1 Summary of Notations and their definitions

<table>
<thead>
<tr>
<th>Notation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_t$</td>
<td>The spot price at time $t$</td>
</tr>
<tr>
<td>$S_{te}^e$</td>
<td>The expected spot exchange rate at time $t$</td>
</tr>
<tr>
<td>$F_t$</td>
<td>The future price at time $t$</td>
</tr>
<tr>
<td>$i_b$</td>
<td>The interest rate of base currency (domestic currency)</td>
</tr>
<tr>
<td>$i_p$</td>
<td>The interest rate of price currency (foreign currency)</td>
</tr>
<tr>
<td>$\Omega_t$</td>
<td>Information set available at time $t$</td>
</tr>
</tbody>
</table>

2.1 Basics of Exchange Rates

An exchange rate is defined as the price of a foreign currency in terms of a domestic currency. There are two ways to represent an exchange rate. The first way is to express the number of units of the domestic currency that can be traded for one unit of the foreign currency. The second way is to express the number of units of the foreign currency that can be traded for one unit of the domestic currency (Feenstra & Taylor 2017). In this research, the domestic currency is always considered as the US dollar, so the second way of expressing the exchange rates is adopted.

A currency might fluctuate in terms of another currency. When a foreign currency buys more of the domestic currency, i.e. the domestic currency becomes cheaper in terms of the foreign currency, it is said that the foreign currency has appreciated. Whereas, when a foreign currency buys less of the domestic currency, i.e. the
domestic currency becomes more expensive in terms of the foreign currency, it is said that the foreign currency has depreciated. (Feenstra & Taylor 2017)

There is a great impact of currency appreciation and depreciation. For example, when the exchange rate of a foreign country depreciates, their exports become cheaper and their imports become more expensive, whilst, the exports of the domestic country become more expensive and the imports become cheaper. Similarly, when the exchange rate of a foreign country appreciates, their exports become more expensive and their imports become cheaper, whilst, the exports of the domestic country become cheaper and the imports become more expensive.

A foreign exchange market is a place where the currencies are bought and sold. The exchange rate (or the price of a currency) is determined when they are traded in exchange for other currencies. In a free market, this is done by the market forces, i.e. the supply and demand.

2.1.1 Exchange Rate Regimes

Exchange rate regimes are categories representing different behaviors of exchange rates. This have been categorized by economists. There are mainly two major types of exchange rate regimes:

1) **Fixed (or pegged) exchange rate regime:** This exchange rate regime has the currency of a country fixed to either another currency, a basket of currencies or another measure of value, such as gold over a sustained period. The monetary authority of a country is responsible to determine the exchange rate and the central bank intervenes to regulate the foreign exchange market and change the interest rates in one or both countries. (Feenstra & Taylor 2017)

2) **Floating (or flexible) exchange rate regime:** In this exchange rate regime, the currency of a country is determined by the supply and demand of that particular currency in the foreign exchange market. There is no government intervention here and therefore, the currency in question might appreciate or
depreciate according to the foreign exchange market conditions. (Feenstra & Taylor 2017)

Furthermore, Bleaney, Saxena and Yin (2018) find that there are more growth collapses in fixed exchange rate regimes than in floating exchange rate regimes. The respective exchange rate regimes for the BRICS are shown in Table 2 below.

**Table 2 Exchange rate regimes of the BRICS (source: IMF 2016)**

<table>
<thead>
<tr>
<th>Country</th>
<th>Exchange Rate Regime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>Floating</td>
</tr>
<tr>
<td>Russia</td>
<td>Floating</td>
</tr>
<tr>
<td>India</td>
<td>Floating</td>
</tr>
<tr>
<td>China</td>
<td>Fixed</td>
</tr>
<tr>
<td>South Africa</td>
<td>Floating</td>
</tr>
</tbody>
</table>

2.1.2 Spot Exchange Rates, Forward Exchange Rates and Arbitrage

A spot exchange rate is the price to exchange one currency for another currency for delivering at the earliest possible date (“on the spot”). This is a generic contract in the foreign market and it is known as the spot contract. Whenever the term “exchange rates” is used, the spot exchange rates are considered. The trades made on spot contracts are considered to be riskless.

Due to pricing differences in the foreign exchange markets, there are profit opportunities that an investor can make. The trading strategy the investor makes is known as arbitrage trading strategy. In simple terms, arbitrage occurs when an investor tries to buy the cheaper financial instruments and sells the more expensive ones. If this situation takes place, then the foreign exchange market will be considered to be not in equilibrium. Therefore, if the opposite circumstance occurs, then the market will be considered to be in equilibrium and will satisfy a condition called as the no-arbitrage condition. (Feenstra & Taylor 2017)
A forward exchange rate is an exchange rate at which an interested party will enter a contract to trade a currency at a time in the future. The interested party becomes sure of the price of the currency that he/she will trade in the future. In this research, three-month forward rates are taken into consideration.

2.2 Covered Interest Rate Parity

The covered interest rate arbitrage parity (CIP) is first discussed since it is an integral part of this research. It shows the relationship between the forward and spot rates. The term “parity” or the condition of parity is the situation when there are equilibria in the forward and spot markets. The CIP condition states that when profits are not expected from arbitrage opportunities, forward rates and the spot rates of a currency pair depend on the interest rates of the two countries in question. This relationship is presented in Equation (1):

$$F_t = \frac{S_t \ast (1 + i_p)}{(1 + i_b)}$$ (1)

In layman terms, this situation is explained as follows: As represented in Figure 1, the proceeds are obtained from borrowing in one currency, then exchanging the currency for another currency, and investing in the second currency using interest-bearing financial assets. Thereafter, concurrently going long on a forward contract to convert the currency back at the holding period’s terminal. This entire procedure should not be able to generate any excess profit. The excess profit is regarded as the profit that is supposed to be equal to a strategy where the investor borrows in the domestic currency and goes long in an interest-bearing financial instrument in the domestic currency. This condition is valid when the market is assumed to be efficient with no transaction costs or the imposition of taxes.
If the CIP condition does not hold, an arbitrage opportunity will take place which means that the investor can earn a risk-free return. In the practical world, according to Du, Tepper and Verdelhan (2018), the CIP condition deviate due to the transaction costs as well as the imposition of taxes on interest payments to foreign investors.

2.3 Uncovered Interest Rate Parity

The uncovered interest rate parity (UIP) is similar to the covered interest rate parity. The only difference between the two is that in uncovered interest rate parity, the expected spot exchange rate of the future time period is used instead of the forward exchange rate. Here, the investor faces the exchange rate risk and he/she must make a forecast of the future spot rate (Feenstra & Taylor 2017). Another way to defined the UIP is the difference between the interest rates of two countries should be equal to the change in the exchange rates at the same time period.

The process can be seen in Figure 2. In UIP, investors are assumed to be indifferent to risk and they are expected to care only about expected returns. Suppose we have 1
unit of foreign currency (i.e. price currency) today but we would like to earn interest in the domestic currency (i.e., base currency). Therefore, we convert the unit of foreign currency into the domestic currency by selling the foreign currency and buying the domestic currency. Thereafter, we invest the domestic currency for a given time period, for instance for one year. After one year, we convert back the proceeds to the foreign currency using the spot exchange rate quoted after one year. The difference between the price of one unit of foreign currency one year ago and the same one year later should correspond to the one-year interest rate in the foreign country. If this phenomenon is true (with no arbitrage opportunities present), then the relationship will be presented as shown in Equation (2):

\[
S_t^e = \frac{S_t \times (1 + i_p)}{(1 + i_b)}
\]  

(2)

Figure 2 Uncovered Interest Rate Parity (adapted from Feenstra & Taylor 2008)
2.4 Efficient Market Hypothesis

The concept of efficient market hypothesis was first introduced by Fama (1970). He affirms that financial markets are efficient as all the available information is present and the prices reflect all the information that is known at a particular time period. Therefore, since the known information has already been incorporated in the prices, it should not be useful for forecasting expected profits. Hence, an interested investor should not be able to outperform the financial market.

Similar to the UIP condition, Fama (1970) also discusses that a simple efficiency hypothesis is a joint hypothesis with an assumption that the market agents are risk neutral and make rational judgements. Hooper and Kohlhagen (1978) argue that the activities of the central banks cannot be ignored in foreign exchange markets when the efficiency of the markets is being tested. This is because the changes made in the monetary policy will have a significant impact in the movements of exchange rates.

Fama (1970) distinguishes between three forms of efficiency in this literature:

1) Weak form efficiency: the current prices have incorporated all the information from the historical prices
2) Semi-strong form efficiency: the current prices have incorporated all the information that is publicly available which include those from the historical prices
3) Strong form efficiency: the current prices reflect all kinds of information, including propriety and insider information, is known.

Figure 3 shows an illustration that provides a visual representation of the three forms of efficiency.
Ţiţan (2015) find that it is difficult to test the market efficiency and it is possible that because of the changes in market/economic conditions, there is a need for developing new theoretical models in order to take all changes into consideration. Moreover, it is not expected for the strong form of efficiency to hold in practice due to confidential and significant activities take place by the central banks that have impacted the foreign exchange markets (Sarno & Taylor 2002). However, investors can expect semi-strong and weak forms of efficiency since it is similar to the rational expectation hypothesis (REH) and therefore, they use all the publicly available information in forming expectations (Sarno & Taylor 2002).

2.5 Rational Expectations Hypothesis

The rational expectation hypothesis (REH) is an economic theory, introduced by Muth (1961), where all investors can make their choices based on their rational outlook, i.e. they can make rational judgements. This can be done with all the available information and past experiences. The theory suggests that the present expectations in the economy is equivalent to what investors think will happen in the future. In the context of international finance, the REH suggests that in order for the
foreign exchange market to be efficient, the future spot rates should be equivalent to the forward rates. In this study, the spot rates three months from now should correspond to the quoted three-month forward rates. According to the REH, the expectation at time, $t$, of the realization of $S$ at time $t + 1$, which can be written as in Equation (3):

$$S_t^e = E_t[S_{t+1} | \Omega_t]$$  \hspace{1cm} (3)

$\Omega_t$ includes all the information concerning the policies to be carried out in the future. Additionally, under the REH, investors formulate unbiased forecasts of forward rates and their forecast error should be equal to zero. This is presented in Equation (4):

$$E_t[S_{t+1}^e - S_{t+1}] = 0$$  \hspace{1cm} (4)

### 2.6 Peso Problem

Evans (1996) describes the peso problem as the skew in the distribution of the forecasted errors from the linear regression that may occur when the investors are fully rational and learn quickly. However, they are uncertain about the future shift in the regime. In other words, it also refers to the situation where the investors associated a small probability to a large change in the economic fundamentals which does not occur in the sample of data. This was first identified in the behavior of the Mexican peso and hence, the name originated from the currency. The Mexican peso followed a fixed rate regime for a decade. However, during the early 1970s, it traded at a forward discount against the US dollar. This reflected the market’s anticipation of a devaluation although this did not occur until 1976.
2.7 Forward Premium Puzzle

As mentioned earlier, if the market is efficient, the forward rate will be equal to the market’s expectation of the spot rate that will be when the forward contract matures. The prediction of the forward rate can vary, but on average, it should be stable (assuming the investors are risk neutral). When this takes place, economists state that the forward rate is an unbiased predictor of the spot rate at a future date.

However, Engel (1996) empirically tested that the forward rate is not an unbiased predictor of the spot rate at a future date. It was seen that when analyzed statistically, the forward rate tends to stay above or below the spot rate for extended periods. There were two reasons for this – one might be the peso problem and the other is the risk premium.

The forward rate will remain below the spot rate if the foreign exchange markets anticipates that the exchange rate will decrease. This is because it is assumed that the forward rate exhibits the market expectation. Evans and Lewis (1995) found out that the peso problem is (but not limited to) a significant component in the forward premium puzzle. Another research was made by Boudoukh, Richardson and Whitelaw (2016) where they find that if we use lagged forward interest rates, instead of spot interest rate differentials in a UIP condition, then forward premium puzzle gets deepened.

2.8 Literature Review

In this section of the theoretical framework, the previous empirical research on the similar topic will be discussed thoroughly. Similar research has already been carried out by various researchers. Some researchers have used the same econometric techniques that have been applied in this research whilst others have used other techniques.

The Johansen cointegration test was used several times for testing the weak form of the EMH. For example, Cicek (2014) tested the within-country market efficiency for the Turkish exchange rates. Secondly, Ahmad, Rhee and Wong (2012) focused on
the Asia-Pacific region when they tested for the foreign exchange market efficiency when the region is under crisis. They found that using the Johansen cointegration test, the markets are generally efficient within-country. However, the efficient market hypothesis does not hold when they used the same test. Therefore, they use Pilbeam and Olmo (2011) model to harmonize the disparity of the previous results. They conclude that countries whose currencies follow a floating rate regime in the market are more resilient than those who follow a managed floating rate regime. They also found that the foreign exchange markets of the Asian countries were more efficient in the 2009 financial crisis than in the 1997-1998 Asian crisis.

Amelot, Ushad and Lamport (2017) tested the EMH in the FX market of Mauritius. For the weak-form, they used the ADF and the Philips Peron (PP) test and for the semi-strong form they also used the Johansen cointegration test, along with the Granger causality test and the variance decomposition.

Variance ratio test, introduced by Lo and McKinlay (1989), has also been a popular alternative for testing the efficiency in the foreign exchange markets. For example, Katusiime, Shamsuddin and Agbola (2015) find that the Ugandan exchange market is pricing inefficient using the variance ratio test. Chiang, Lee, Su and Tzou (2010) also used variance ratio test for re-examining the weak form efficiency market hypothesis for foreign exchange markets in four floating rate markets in Asian countries (Japan, South Korea, Taiwan and the Philippines).

Another study was carried out for 12 countries in the Asia-Pacific region by Azad (2009) where the empirical tests for random walk and the efficiency of the exchange markets were performed. Azad (2009) used panel unit root test as well as variance ratio test on high (daily) and medium (weekly) data post the Asian financial crisis. The unit root tests were also used by Matebejana, Motlaleng and Juana (2017) for studying the random walk behavior of the exchange rates in Botswana.

The unbiased forward rate hypothesis (UFH) has been tested by many researchers in the past, especially in the South Asian countries. For instance, Kumar and Mukherjee (2007) tested whether the forward rate is an unbiased predictor of the future spot rate for the Indian rupee against the US dollar. They found that the UFH fails in the
Indian context. Additionally, Sikdar and Mukhopadhyay (2017) does a similar research in the Indian context where they study about the efficiency of the Indian FX market and see whether there is any relevance of the CIP condition. Similarly, Bashir, Shakir, Ashfaq and Hassan (2014) carries out a related research where they tested the efficiency of the exchange market in Pakistan. They find that the forward exchange rate does not fully reflect the information available. Also, Wickremasinghe (2016) tests the validity of the weak and semi-strong form of efficiencies in the foreign exchange markets of Sri Lanka. He finds that the Sri Lankan foreign exchange market is consistent with both the weak and semi-strong form of the EMH.

The test for the efficiency for the BRICS has also been carried out by Kumar and Kamaiah (2016) where they not only examine the presence of the weak form of the EMH but also non-linearity and the chaotic behavior of the FX markets. However, they use the variance ratio test, BDS test, Hinich Bispectrum test, Teräsvirta Neural Network test and the estimation of Largest Lyapunov exponents (LLE’s) for examination.

In this particular research, the Johansen cointegration test is performed (after constructing the bivariate VAR models and the VECMs) for testing the efficiency of the FX markets in the BRICS. As per the literature of international finance, this method has never been applied on the BRICS countries. Therefore, we will proceed further to the next chapter in order to discuss the methodology adopted for this study.
3 DATA AND RESEARCH METHODOLOGY

This section of the thesis will reiterate the research objectives and specify the sources of the data used and discuss the research methodology in detail. The objective of this section is to provide the reader the necessary tools to understand the thesis in an unambiguous way.

3.1 Research Objective

The objective of this research is to test whether the foreign exchange markets in emerging economies are efficient. Thus, the relevant hypothesis is presented as follows:

$H_0$: The FX market of a particular emerging economy is efficient.

$H_1$: The FX market of a particular emerging economy is not efficient.

The uncovered interest rate parity and the efficient market hypothesis will be tested for efficiency. Therefore, the hypothesis is further divided into three questions which are listed below:

1) Does the uncovered interest parity hold empirically for every country?
2) Does the unbiased forward rate hypothesis/rational expectations hypothesis hold for every country?
3) Does the efficient market hypothesis hold for every country?

In order to test these research questions, econometric tools such as OLS estimators, bivariate Vector Autoregression (VAR) models, Vector Error Correction models (VECM) and Johansen cointegration tests are going to be used in this research. These tools will be discussed in details in this section.
3.2 Data

In this research, spot and three-month non-deliverable forward rates are used of five emerging economies. These countries are Brazil, China, India, Russia and South Africa (BRICS). These countries were chosen because of two reasons – 1) they are the five major emerging economies in the world and showcase significant influence on their respective region and 2) the data for these countries were easier to obtain compared to that of other emerging economies.

The dataset is based on time-series with the relevant foreign currency against the US dollar. It includes monthly exchange rates within a time period of fourteen years and one month, i.e., from 31\textsuperscript{st} March 2004 to 30\textsuperscript{th} April 2018, and it has been obtained from DataStream by Thompson Reuters.

In addition to spot and forward rates, the corresponding interest rates for the five countries were also collected. Since three-month forward rates were chosen, three-month interest rates (quoted on a monthly basis) were obtained for this research. The three-month Treasury bill is used as the interest rate for the base currency (i.e. the US dollar in this case). Similarly, the equivalent interest rates are used for the other five countries. The interest rates follow the same time frame as the spot and forward rates.

The data for interest rates were obtained from three different sources. Thompson Reuters DataStream, the website of Federal Reserve Bank of St. Louis (FRED) and the website of the Organization for Economic Co-operation and Development (OECD) were the three sources for the interest rates.

The R software is used for this research. Furthermore, the logarithmic transformation is used for all the variables in the research (except in the descriptive statistics). This is because logarithmic values help in scaling down the variables and “smoothening” the trend in the time series plots which helps in the study.

In the remaining part of the section, the econometric tools and its applications used for testing the research question will be discussed.
3.3 Methodology

In this section of the chapter, the methodology applied in the study is discussed. The section provides the reader with a detailed explanation on the econometric tools and the logical reasoning behind using the tools.

3.3.1 Skewness and Kurtosis

Before we started researching about the main research questions, we used the skewness and the kurtosis to understand the behavior of the spot and forward rates. Skewness is a measure of symmetry of distribution and the kurtosis is the measure for the degree of tailedness in a distribution. The skewness, $SK$, and the kurtosis, $KT$, are defined in Equation (5.1) and Equation (5.2), respectively.

\[
SK = \frac{1}{T} \sum_{t=1}^{T} \left( \frac{z_t}{\sigma_z} \right)^3
\]  

(5.1)

\[
KT = \frac{1}{T} \sum_{t=1}^{T} \left( \frac{z_t}{\sigma_z} \right)^4
\]  

(5.2)

3.3.2 UIP Condition

In order to check whether the UIP condition holds, we test whether the following regression holds. We are testing whether the difference between the spot rate at time $t + 3$ and the current spot rate is defined by the difference between the interest rate from the price currency and the interest rate from the base currency (i.e. the three-month US Treasury bill). The regression is shown in Equation (6):

\[
\text{Regression Equation}
\]
\[
\ln(S_{t+3}) - \ln(S_t) = \alpha + \beta(i_p - i_b) + \epsilon_{t+1} \quad (6)
\]

As mentioned earlier, \(S_{t+3}\) denotes the spot rate at time \(t+3\).\(^1\) We first examine whether \(\alpha = 0\) and \(\beta = 1\) is present using the linear regression. If \(\alpha = 0\) and \(\beta = 1\), then we can conclude that the UIP condition holds. The test is applied to all the countries and the results are presented in the next chapter.

### 3.3.3 Augmented Dickey-Fuller Test

Dickey and Fuller (1979) introduced the dickey-fuller test to be used for normal scenarios, for testing for the presence of unit root. However, we use the augmented dickey-fuller (ADF), suggested by Elliott, Rothenberg and Stock (1996), to test in this research. The reason for using the ADF test is that it can accommodate higher-order autoregressive processes in the error term, \(\epsilon_{t+1}\).

In this research, we perform the ADF test in order to find the order of integration. The augmented dickey-fuller test is given in Equation (7):

\[
ADF\ -\ test = \frac{\hat{\beta} - 1}{\text{std}(\hat{\beta})} \quad (7)
\]

Where \(\hat{\beta}\) denotes the least squares estimate of \(\beta\). The null and alternative hypotheses are as follows: \(H_0: \beta = 1\) versus \(H_0: \beta < 1\). The results of the ADF test and the order of integration of the five countries are attached in Appendix 1.

---

\(^1\) The definitions of the other notations are given in page 12.
3.3.4 Unbiased forward rate hypothesis/CIP and UIP

Next, we test whether the unbiased forward rate hypothesis/rational expectations hypothesis holds. This test is also an amalgamation of the UIP condition and the CIP condition. A similar regression-based analysis is used that we have applied in testing the UIP condition. Therefore, the linear regression for the UFH/REH is presented in Equation (8):

\[
\ln(S_{t+3}) = \alpha + \beta(F_t) + \varepsilon_{t+1}
\]  (8)

This test is checking whether the three-month forward rate of a particular country is an unbiased estimator of the corresponding spot rate at time \(t + 3\) for that country. In order to satisfy this condition, we need to have a joint null hypothesis where \(H_0: \alpha = 0\) and \(H_0: \beta = 1\). If these are not satisfied, then we can conclude that the forward rate does not explain the spot rate three-months from now and also, it is not the unbiased estimator of the corresponding spot rate three-months from now.

3.3.5 Vector Autoregressive (VAR) models

We use bivariate vector autoregressive model to obtain a better estimated model for the spot and forward rates than the linear regression. The VAR model is implemented because one can use the least-squares (LS) estimates which are equivalent to the maximum likelihood (ML) estimates. Similarly, the OLS estimates are equivalent to the generalized least-squares (GLS) estimates. Sims (1980) had suggested that using VAR models for macroeconomic research would be favorable.

The main advantages are that we do not need to specify which variables are endogenous and which ones are exogenous. They all are endogenous. VAR models provide that there are no coexistent terms on the right-hand side of the equations, can simply use OLS separately on each equation. Secondly, these models’ forecasts are often better that “traditional structural” models.
The structure of a VAR model with a multivariate time series \( z_t \), where \( z_t = (z_{1t}, z_{2t}, \ldots, z_{kt})' \) with \( k \) random variables and order of \( p \), \( \text{VAR}(p) \) is shown in Equation (9):

\[
z_t = \phi_0 + \sum_{i=1}^{p} \phi_i z_{t-i} + a_t
\]  

(9)

Where \( \phi_0 \) is a \( k \)-dimensional constant vector and \( \phi_i \) are \( k \times k \) matrices for \( i > 0 \), \( \phi_p \neq 0 \), and \( a_t \) is a sequence of independent and identically distributed (iid) random vectors with mean zero and covariance matrix \( \Sigma_a \) which is positive definite.

In this research, we use the bivariate VAR model since there are two variables. For example, a bivariate VAR(1) model for this study with spot and forward rates will look similar to Equation (10):

\[
\begin{pmatrix}
  s_{1t} \\
  f_{2t}
\end{pmatrix}
= \begin{pmatrix}
  \phi_{10} & \phi_{11} \\
  \phi_{21} & \phi_{22}
\end{pmatrix}
\begin{pmatrix}
  s_{1t-1} \\
  f_{2t-1}
\end{pmatrix}
+ \begin{pmatrix}
  a_{1t} \\
  a_{2t}
\end{pmatrix}
\]

(10)

The order selection of the VAR models for each country is decided based on Akaike information criteria (AIC) which is discussed in the following sub-section.

**Akaike’s Information Criteria (AIC)**

Proposed by Akaike (1973), the AIC helps us choose the optimal lag-order for a VAR model. Choosing the optimal lag-order is essential. This is because if we choose too many lags, we will lose out on a lot of degrees of freedom and if too few lags are included, then our models will be unreliable. The autocorrelation of the error
terms could lead to apparently significant and inefficient estimators, thus, giving us wrong results. The formula for AIC is given in Equation (11):

$$AIC(l) = \ln|\Sigma_{a,l}| + \frac{2}{T}lk^2$$  \hspace{1cm} (11)

Where $T$ denotes the sample size and $\Sigma_{a,l}$ is the ML estimate of $\Sigma_a$.

**Portmanteau test**

The Portmanteau statistic is used for testing the lack of up to the order $h$ for serially correlated disturbances in a stable VAR($p$). One type of portmanteau test is the Ljung-Box test, introduced by the Ljung and Box (1978), that was used for the univariate series. However, Hosking (1980) extended the Ljung-Box test statistic so that it would be appropriate to use the same test statistic in the case of multivariate series. According to Hosking (1980), the multivariate test statistic for serial correlation is shown in Equation (12):

$$LB - statistic = T(T + 2) \sum_{j=1}^{s} \frac{1}{T-j} tr\{C_{0j}C_{00}^{-1}C_{0j}'C_{00}^{-1}\} \sim \chi^2_{k(s-L)}$$  \hspace{1cm} (12)

Where,

$$C_{0j} = T^{-1} \sum_{t=j+1}^{T} \varepsilon_t \varepsilon'_{t-j}$$  \hspace{1cm} (12.1)
The Ljung-Box test statistic follows a $\chi^2$ distribution with $k(s - L)$ degrees of freedom. $T$ denotes the length of the series, and $s$ denotes the order of autocorrelation. The test can be implemented only when the order of autocorrelation is higher than the lag length in the VAR model, i.e. $s > L$.

**Multivariate Jarque-Bera test**

Next, we look at the test of normality for the multivariate series. Kilian and Demiroglu (2000) introduced the new version of Jarque-Bera test of normality (which was introduced by Jarque and Bera (1980)) for multivariate series. The test statistic is defined in Equation (13):

$$JB - \text{statistic} = \frac{T}{6}SK + \frac{T}{24}KT \xrightarrow{T \to \infty} \chi^2(2n)$$  \hspace{1cm} (13)

Where the skewness as well as the kurtosis is defined in Equation (13.1) and Equation (13.2):

$$SK = \frac{T^{-1} \sum_{t=1}^{T} \tilde{W}_{it}^3}{(T^{-1} \sum_{t=1}^{T} \tilde{W}_{it}^2)^{3/2}} \quad i = 1,...,n$$  \hspace{1cm} (13.1)

$$KT = \frac{T^{-1} \sum_{t=1}^{T} \tilde{W}_{it}^4}{(T^{-1} \sum_{t=1}^{T} \tilde{W}_{it}^2)^{2}} \quad i = 1,...,n$$  \hspace{1cm} (13.2)

$\tilde{W}_{it}$ denote the elements of a matrix $\tilde{W}$ which consists of the individual skewness and kurtosis measures based on the standardized residuals matrix.
**Multivariate ARCH-LM test**

The multivariate ARCH-LM test is used to check whether the residuals obtained from a VAR($p$) model follows an autoregressive conditional heteroskedasticity. Lütkepohl (2006) gives us the following explanation for the multivariate ARCH-LM test:

The test is based on the following regression presented in Equation (14):

\[
vech(\hat{\epsilon}_t\hat{\epsilon}_t') = \beta_0 + B_1 vech(\hat{\epsilon}_{t-1}\hat{\epsilon}_{t-1}') + \cdots + B_q vech(\hat{\epsilon}_{t-q}\hat{\epsilon}_{t-q}' + \nu_t) \quad (14)
\]

Where $\nu_t$ is a spherical error process and $vech$ is the column-stacking operator for symmetric matrices that stacks the columns from the main diagonal on downwards. The dimension $\beta_0$ is $\frac{1}{2} K(K + 1)$ and for the coefficient matrices $B_i$ with $i = 1, \ldots, q, \frac{1}{2} K(K + 1) \times \frac{1}{2} K(K + 1)$. The null hypothesis is $H_0 : B_1 = B_2 = \cdots = B_q = 0$ and the alternative hypothesis $H_1 : B_1 \neq 0$ or $B_2 \neq 0$ or $\cdots$ $B_q \neq 0$. The test statistic is in Equation (14.1):

\[
VARCH_{LM}(q) = \frac{1}{2} TK(K + 1) R_m^2 \quad (14.1)
\]

with

\[
R_m^2 = 1 - \frac{2}{K(K + 1)} tr(\hat{\Omega}_0 \hat{\Omega}_0^{-1}) \quad (14.2)
\]
and $\hat{\Sigma}$ assigns the covariance matrix of the regression model previously mentioned.

The test statistic is distributed as $\chi^2 (qK^2 (K + 1)^2 / 4)$.

3.3.6 Vector Error Correction models

In order to perform the Johansen cointegration test, we need to convert our VAR models into reduced forms. Vector error correction models are the reparametrized models that help to bring the order of integration from $I(1)$ to $I(0)$, i.e. if the VAR models are non-stationary, the VECM help to make them stationary. A VECM of a bivariate VAR(1) model would look like that in Equation (15.1) or in Equation (15.2):

$$
\begin{pmatrix}
    s_{1t} - s_{1t-1} \\
    f_{2t} - f_{2t-1}
\end{pmatrix} =
\begin{pmatrix}
    \phi_{10} \\
    \phi_{20}
\end{pmatrix}
\begin{pmatrix}
    \phi_{11} - 1 & \phi_{12} \\
    \phi_{21} & \phi_{22} - 1
\end{pmatrix}
\begin{pmatrix}
    s_{1t-1} \\
    f_{2t-1}
\end{pmatrix}
+ \begin{pmatrix}
    a_{1t} \\
    a_{2t}
\end{pmatrix}
$$

(15.1)

or

$$
\begin{pmatrix}
    \Delta s_{1t} \\
    \Delta f_{2t}
\end{pmatrix} =
\begin{pmatrix}
    \phi_{10} \\
    \phi_{20}
\end{pmatrix}
\begin{pmatrix}
    \pi_{11} & \pi_{12} \\
    \pi_{21} & \pi_{22}
\end{pmatrix}
\begin{pmatrix}
    s_{1t-1} \\
    f_{2t-1}
\end{pmatrix}
+ \begin{pmatrix}
    a_{1t} \\
    a_{2t}
\end{pmatrix}
$$

(15.2)

Where $\pi_{11} = \phi_{11} - 1, \pi_{12} = \phi_{12}, \pi_{21} = \phi_{21}$ and $\pi_{22} = \phi_{22} - 1$

or

$$
\Delta z_t = \phi_0 + \pi z_{t-1} + a_t
$$

(15.3)

The bold letters in Equation 15.3 denote time series of $s_{1t}$ and $f_{2t}$ in vector forms.
3.3.7 Johansen Cointegration tests

Johansen (1991) explains a procedure for testing the cointegration test for multiple time series which have an order of integration of $I(1)$. We use the Johansen cointegration test in our research because this test permits more than one cointegrating relationship. This is the most appropriate test for our bivariate VAR models. The test depends on the rank of the matrix $\pi = \begin{pmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{pmatrix}$ which is found in the VECM.

The conditions for cointegration are as follows:

1) If $s_{1t}$ and $f_{2t}$ have the order of integration of $I(0)$ if the rank of the matrix $\pi$ is 2. This means that the matrix $\pi$ contains 2 cointegrating vectors. Any linear combination of $s_{1t}$ and $f_{2t}$ is known to be stationary. Also, $s_{1t}$ and $f_{2t}$ are known to be ‘trivially cointegrated’, and therefore, calling the two series ‘cointegrated’ is not necessary.

2) If the matrix $\pi$ has a rank of 1, that means the matrix has 1 cointegrating vector, a linear combination of $s_{1t}$ and $f_{2t}$ will exist which will be stationary, i.e. $I(0)$, and $s_{1t}$ and $f_{2t}$ are cointegrated.

3) If the matrix $\pi$ has a rank of 0, that means the matrix has zero cointegrating vectors, a stationary linear combination of $s_{1t}$ and $f_{2t}$ will not exist, and $s_{1t}$ and $f_{2t}$ are not cointegrated.

In order to test the rank of the matrix, we need to test the hypotheses that concerns the rank. Johansen (1991) developed two test statistics which are known as the trace statistic ($\lambda_{trace}$) and maximal eigenvalue statistic ($\lambda_{max}$).

The likelihood ratio test for the trace statistic is shown in Equation (16.1):
\begin{equation}
\lambda_{trace} = -T \sum_{i=r_0+1}^{n} \ln(1 - \lambda_i)
\end{equation}

(16.1)

Where \( n \) is the maximum number of possible cointegrating vectors, \( \lambda_i \) are the eigenvalues and \( r_0 \) denotes the rank of a matrix. The name “trace” in trace test denotes the test statistic’s asymptotic distribution is the trace of a matrix based on functions of Brownian motion or standard Wiener processes (Johansen 1995).

The likelihood ratio test for the maximal eigenvalue statistic is shown in Equation (16.2):

\begin{equation}
\lambda_{\text{max}} = -T \ln(1 - \lambda_{r_0+1})
\end{equation}

(16.2)

(The notations for the maximal eigenvalue statistic are the same as in the trace statistic.)

There are two stages of hypothesis testing in Johansen cointegration test for bivariate model. The summary of hypotheses is presented in Table 4. There are slight differences in the hypotheses for the test statistics, but the outcomes are equivalent in both methods.

\begin{table}[h]
\centering
\caption{Summary of hypotheses for Johansen cointegration tests}
\begin{tabular}{|c|c|c|}
\hline
Stage & \( \lambda_{trace} \) & \( \lambda_{\text{max}} \) \\
\hline
Stage 1 & & \\
& \( H_0: r_0 = 0 \) & \( H_0: r_0 = 0 \) \\
& \( H_1: r_0 > 0 \) & \( H_1: r_0 = 1 \) \\
Stage 2 & & \\
& \( H_0: r_0 \leq 1 \) & \( H_0: r_0 \leq 1 \) \\
& \( H_1: r_0 = 2 \) & \( H_1: r_0 = 2 \) \\
\hline
\end{tabular}
\end{table}
In stage 1, if \( H_0 \) is accepted, this means that the series have an order of integration \( I(1) \) and they are not cointegrated. The testing of cointegration can be stopped here. Otherwise, if \( H_0 \) is rejected, we proceed to stage 2. In the second stage, if \( H_0 \) is accepted, this means that the series have an order of integration \( I(1) \) and they are cointegrated. If \( H_0 \) is rejected, then the series have an order integration \( I(0) \).

If we find that the spot and the forward rates are cointegrated, then this means that there is a long-term relationship among the variables and the foreign exchange markets are not efficient and the weak and semi-strong form of efficient market in EMH is rejected. However, if we find that the spot and forward rates are not cointegrated, then it means that there is no long-term relationship present. Therefore, we can say that foreign exchange market is efficient and we fail to reject the weak and the semi-strong form of EMH.

3.3.8 Application of research methodology

The bivariate VAR models, VECM and their corresponding Johansen integration tests are used to test the simple efficient hypothesis. Hakkio (1981) and Baillie, Lippens and McMahon (1983) suggests to use this method on spot and forward rates. However, it was found later in the cointegration literature that if first difference is taken into consideration in a VAR model, it may not be appropriate for the spot and forward rates since if the variables both have the order of integration of \( I(1) \), and cointegrated, then the bivariate VAR models with first differences would be misspecified because the error correction terms are omitted (Engle and Granger 1987). Therefore, we have not first differenced the variables for VAR models in this research but have used the VECM after constructing the VAR models.
In addition to test the spot and forward rates, we have also modelled the forward premium, \( f_t - s_t \), and the rate of depreciation, \( \Delta s_t^2 \), as a bivariate VAR model as in Equation (17):

\[
z_t = \sum_{i=1}^{m} \phi_i z_{t-i} + a_t
\]  

(17)

Where \( z'_t = [\Delta s_t, f_t - s_t] \), \( \phi_i \) represent the matrices of coefficients, \( a_t \) is assumed to be a bivariate vector of white noise processes and \( m \) is the appropriately chosen order of lag.

The same process, i.e. forming the corresponding VECM and thereafter proceeding with the Johansen cointegration tests, are used to test the simple efficient hypothesis. The results of this version of the test will determine whether the member countries of the BRICS are efficient, which will ultimately lead to the conclusion of this research.

\[2 \Delta s_t = s_{t+3} - s_t \], this denotes the difference between the spot rate at time \( t + 3 \) and the current spot rate.
4 EMPIRICAL RESULTS

In this section, the results of the tests discussed in the research methodology section are presented and analyzed thoroughly. The purpose of this section is to give the reader a comprehensive analysis of all the results for all the BRICS countries. As mentioned in the previous section, the R software was used for this research.

Table 4 shows the descriptive statistics of both the spot and forward rates for each of the five countries in question. These values are not the results of logarithmic transformation since we want to study the behavior of the quoted spot and forward rates.

From the table, we can observe that Russian ruble and the India rupee have the highest standard deviation for both spot and forward rates. Secondly, all the countries have positively skewed distribution which mean they are all skewed to the right. The Russian ruble has the highest skewness among all the countries where as the Indian rupee has the lowest skewness. The Brazilian real, the Chinese yuan and the South African rand have skewness that ranges from 0.7 to 0.8. Moreover, all the countries have positive kurtosis which means that they have leptokurtic distributions (i.e. fatter tails). The kurtosis ranges from 1.5 to 2.8. In this case, the Russian ruble has the highest kurtosis among the other countries and India has the lowest kurtosis.

Figure 4 shows the patterns of all the spot and forward rates for all the countries. The blue trend represents the spot rates whereas the red trends represents the 3-month forward rates.
Table 4 Descriptive Statistics of Spot and 3-month Forward rates of BRICS

<table>
<thead>
<tr>
<th>Descriptive Statistics</th>
<th>Brazilian real</th>
<th>Russian ruble</th>
<th>Indian rupee</th>
<th>Chinese yuan</th>
<th>South African rand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spot</td>
<td>Forward</td>
<td>Spot</td>
<td>Forward</td>
<td>Spot</td>
</tr>
<tr>
<td>Mean</td>
<td>2.388</td>
<td>2.432</td>
<td>37.45</td>
<td>38.12</td>
<td>52.57</td>
</tr>
<tr>
<td>Minimum</td>
<td>1.555</td>
<td>1.584</td>
<td>23.43</td>
<td>23.5</td>
<td>39.32</td>
</tr>
<tr>
<td>Maximum</td>
<td>4.02</td>
<td>4.13</td>
<td>75.2</td>
<td>77.11</td>
<td>68.45</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.637</td>
<td>0.658</td>
<td>14.402</td>
<td>14.933</td>
<td>9.261</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.757</td>
<td>0.781</td>
<td>1.174</td>
<td>1.163</td>
<td>0.366</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>2.538</td>
<td>2.599</td>
<td>2.798</td>
<td>2.792</td>
<td>1.570</td>
</tr>
</tbody>
</table>

**Note:** Number of observations = 170
Figure 4 Spot and 3-month Forward rates of the BRICS countries
Table 5 shows the results obtained from testing the UIP condition. Here, we look at whether the difference between the spot rate at time \( t + 3 \) and the actual spot rate is completely explained by the interest rate differential. The logarithmic transformation was taken into consideration. We will also check whether the joint null hypothesis of \( \alpha = 0 \) and \( \beta = 1 \) holds. In order to do so, the ordinary least squares method is used as mentioned in the previous section.

It can be observed from the table that the adjusted R-squared for all the BRICS countries are ranging from -0.006 to 0.074. This means that the interest rate differential has been able to explain the difference between the quoted future spot rate and the actual spot rate only 2.62% of the time on average. Another evidence that was found was the standard error of regression is significantly low for all the countries. The smaller the standard error is, the more accurate the predictions are.

The intercepts for the Chinese yuan, the Indian rupee and the South African rand are significant since the null hypotheses that the respective coefficients are zero can be rejected at a certain significance level. The coefficient of the Chinese yuan is rejected at 0.1% significance level, whereas, the same for the Indian rupee and the South African rand are rejected at 5% significance level. Therefore, we can conclude that the intercepts for these currencies differ substantially from zero. As far as the intercepts of the Brazilian real and the Russian ruble is concerned, since their corresponding p-values are higher than 5% significance level, we can conclude that the intercepts of these currencies are insignificant (which means that they do not differ substantially from zero).

On the other hand, as far as the coefficients of the interest rate differentials are concerned, the coefficients of all the currencies of the BRICS countries are significant as the null hypotheses of them being one are rejected at 0.1% level of significance.

As mentioned previously, in order for the UIP condition to hold, the intercept needs to be zero and the coefficient of the interest rate differential needs to be one. Based on our results in Table 5, we can observe that the coefficients for the interest rate differentials are significant for all the countries and the intercepts of the Chinese
yuan, the Indian rupee and the South African rand are also significant (with that of the Brazilian real and the Russian ruble not being significant). Thus, we can conclude that the UIP condition does not hold for any of the currencies for the BRICS countries.
Table 5 Results from testing Uncovered Interest rate parity

<table>
<thead>
<tr>
<th>Currency</th>
<th>Intercept</th>
<th>Interest rate differential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \alpha )</td>
<td>( \beta )</td>
</tr>
<tr>
<td></td>
<td>Coefficient (Std. error)</td>
<td>t-statistic (p-value)</td>
</tr>
<tr>
<td>Brazilian real</td>
<td>0.005</td>
<td>-0.032***</td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.226)</td>
</tr>
<tr>
<td>Chinese yuan</td>
<td>-0.008***</td>
<td>-5.795</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.595)</td>
</tr>
<tr>
<td>Indian rupee</td>
<td>-0.014*</td>
<td>-2.027</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.123)</td>
</tr>
<tr>
<td>Russian ruble</td>
<td>0.007</td>
<td>0.512</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.158)</td>
</tr>
<tr>
<td>South African rand</td>
<td>0.043*</td>
<td>2.000</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.381)</td>
</tr>
</tbody>
</table>

**Note:** The results are obtained from the test \( s_{t+3} - s_t = \alpha + \beta(i - i^*) + \epsilon_{t+1} \) where \( s_{t+3} \) and \( s_t \) are the spot rate at time \( t + 3 \) and the current spot rate respectively, for each country, \( i \) represents the 3-month short-term interest rate of the country in question and \( i^* \) represents the 3-month short term interest rate of the base currency (i.e. the Treasury bill of the United States in this research). All variables have been tested for stationarity before running the regressions. The p-values are bold to represent that the significance of the coefficients. * = 0.05 level of significance, ** = 0.01 level of significance, and *** = 0.001 level of significance.
Table 6 shows the results obtained from testing the unbiased forward rate hypothesis/rational expectations hypothesis, i.e. whether the three-month forward rate is an unbiased predictor of the corresponding spot rate at time $t + 3$. In order to satisfy this condition, we need to have a joint null hypothesis where $H_0: \alpha = 0$ and $H_0: \beta = 1$. Similar to the previous test, the logarithmic transformation was taken into consideration. The ordinary least squares method is also used in this case.

First of all, the adjusted R-squared for all the currencies for the BRICS countries are positive and range from 0.89 to 0.98. This is favorable as it means that the three-month forward rates have been able to explain the spot rate at time $t + 3$ 93.36% of the time on average. Secondly, the standard error of regression for this test for all the countries is low. They range from 0.014 to 0.090. The Russian ruble has the highest standard error among all the countries whereas the Chinese yuan has the lowest.

The coefficients for the three-month forward rates of all the BRICS countries, except for the Chinese yuan, are significant since the null hypothesis of them being one is rejected at 5% level of significance. The coefficient for the three-month forward rate for the Chinese yuan is insignificant as we fail to reject the null hypothesis that the coefficient is equal to one. Also, the intercepts for the Chinese yuan and the Indian rupee are significant as the null hypotheses of them being zero are rejected at 5% significance level. Whereas, the intercepts of the Brazilian real, the Russian ruble and the South African rand are insignificant at any significance level.

Consequently, as per the joint null hypothesis, we can observe that for all the currencies, either the intercept or the coefficient of the 3-month forward rate is significant (both of them are significant in the case of the Indian rupee). Therefore, we can conclude that the forward rates are not unbiased predictors of the corresponding spot rates at time $t + 3$. In other words, the UFH does not hold for any of the currencies.
Table 6 Results of the OLS test for the Unbiased forward rate hypothesis

<table>
<thead>
<tr>
<th>Currency</th>
<th>Intercept</th>
<th>3-month forward rate</th>
<th>S.E. of regression</th>
<th>Adjusted R-squared</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\alpha$</td>
<td>$\beta$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coefficient (Std. error)</td>
<td>Coefficient (Std. error)</td>
<td>t-statistic (p-value)</td>
<td>t-statistic (p-value)</td>
</tr>
<tr>
<td>Brazilian real</td>
<td>0.034 (0.022)</td>
<td>0.942* (0.025)</td>
<td>-2.293 (0.011)</td>
<td>0.083</td>
</tr>
<tr>
<td>Chinese yuan</td>
<td>-0.053* (0.022)</td>
<td>1.026 (0.111)</td>
<td>2.249 (0.987)</td>
<td>0.014</td>
</tr>
<tr>
<td>Indian rupee</td>
<td>0.165* (0.073)</td>
<td>0.957* (0.018)</td>
<td>-2.323 (0.010)</td>
<td>0.042</td>
</tr>
<tr>
<td>Russian ruble</td>
<td>0.137 (0.074)</td>
<td>0.961* (0.0207)</td>
<td>-1.885 (0.029)</td>
<td>0.090</td>
</tr>
<tr>
<td>South African rand</td>
<td>0.087 (0.046)</td>
<td>0.958* (0.021)</td>
<td>-1.985 (0.023)</td>
<td>0.077</td>
</tr>
</tbody>
</table>

Note: The results are obtained from the test $s_{t+3} = \alpha + \beta f_t + \epsilon_{t+1}$ where $s_{t+3}$ and $f_t$ are the spot rate at time $t + 3$ and the forward rate respectively for each country. All variables have been tested for stationarity before running the regressions. The p-values are bold to represent that the significance of the coefficients. * = 0.05 level of significance, ** = 0.01 level of significance, and *** = 0.001 level of significance.
Table 7 below summarizes the behavior of the residuals of the bivariate VAR models which consisted of spot and forward rates. We show the behavior of the residuals instead of presenting the coefficients because there are numerous variables in the VAR models. Logarithmic transformations were taken into consideration. As mentioned earlier, the lag order is determined by Akaike’s information criteria.

The Portmanteau test is used for serial correlation among the residuals for multivariate time series models. It can be observed from the table that none of the countries have significant values for the Portmanteau test. This means that we fail to reject the null hypothesis of no serial correlation among the residuals. Therefore, it can be concluded that there is no sign of serial correlation present for any of the VAR models.

Secondly, we look at the multivariate Jarque-Bera normality test for the residuals. It can be observed that the test statistics for all the countries are significant which means that we reject the null hypothesis of the residuals following a normal distribution at 0.1% significance level. Thus, it can be concluded that the residuals of the bivariate VAR models for spot and forward rates for all the BRICS countries do not follow normal distribution.

Finally, we look at the test statistic for the autoregressive conditional heteroskedasticity (ARCH). Except for the Brazilian real, all other currencies have significant test statistics where the null hypothesis of ARCH models are not present is rejected at 0.1% level of significance. However, we fail to reject the null hypothesis in Brazil’s case. Therefore, we can conclude that ARCH is not present in the bivariate VAR model for the Brazilian real but ARCH is present for all other currencies.

In order to study the residuals of the bivariate VAR models visually, Figure 5 provides an illustration to appreciate the behavior of both spot and forward rates and the residuals. It can be observed that the spot and the forward rates have been closely estimated by the bivariate VAR model. The corresponding residuals of these variables are stationary. Furthermore, the graphs of autocorrelation as well as the partial autocorrelation are also given. As far as the ACF of the residuals is
concerned, we can notice that the lag order of zero is significant in all the variables for all the countries. Similarly, the partial autocorrelation of the residuals is not significant as they have not crossed the blue dotted line in the PACF graphs in Figure 5.
Table 7 Summary of bivariate VAR models of Spot and Forward rates

<table>
<thead>
<tr>
<th>Currency</th>
<th>Lag order</th>
<th>Portmanteau t-statistic (p-value)</th>
<th>Multivariate JB t-statistic (p-value)</th>
<th>Multivariate ARCH t-statistic (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazilian real</td>
<td>1</td>
<td>48.829</td>
<td>113510***</td>
<td>45.764</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.848)</td>
<td><strong>(0.000)</strong></td>
<td>(0.440)</td>
</tr>
<tr>
<td>Chinese yuan</td>
<td>5</td>
<td>31.986</td>
<td>200.540***</td>
<td>99.394***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.911)</td>
<td><strong>(0.000)</strong></td>
<td><strong>(0.000)</strong></td>
</tr>
<tr>
<td>Indian rupee</td>
<td>6</td>
<td>52.780</td>
<td>69.088***</td>
<td>101.270***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.085)</td>
<td><strong>(0.000)</strong></td>
<td><strong>(0.000)</strong></td>
</tr>
<tr>
<td>Russian ruble</td>
<td>5</td>
<td>32.943</td>
<td>56080***</td>
<td>133.770***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.889)</td>
<td><strong>(0.000)</strong></td>
<td><strong>(0.000)</strong></td>
</tr>
<tr>
<td>South African rand</td>
<td>3</td>
<td>61.634</td>
<td>236.520***</td>
<td>149.410***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.169)</td>
<td><strong>(0.000)</strong></td>
<td><strong>(0.000)</strong></td>
</tr>
</tbody>
</table>

**Note:** The lag order is determined based on Akaike’s information criteria. The Portmanteau test is used for serial correlation. The p-values are bold to represent that the significance of the coefficients. * = 0.05 level of significance, ** = 0.01 level of significance, and *** = 0.001 level of significance.
Figure 5 Residuals of the bivariate VAR models for spot and forward rates of the BRICS countries
Table 8 shows the results of the Johansen cointegration tests. The bivariate VAR models were converted to VECM in order to check the ranks of the matrices (additional information is given in the research methodology section of this thesis). The test statistics for both the maximal eigenvalue test and the trace test has been provided. There are slight differences in the test statistics but the conclusion is equivalent for both the methods. Therefore, the analysis will be done once for each currency.

We reject the null hypothesis that the rank of the matrix of VECM for the Brazilian real is equal to zero because the test statistic (for both maximal eigenvalue and trace) is more than the critical value. Therefore, we can proceed to Stage 2. In the second stage, we see that the null hypothesis that the rank of the matrix is less than or equal to zero as the test statistic is less than the critical value. Therefore, it can be concluded that, in the case of the Brazilian real, the spot and forward rates have the order of integration $I(1)$ and are cointegrated.

Secondly, we reject the null hypothesis that the rank of the matrix of VECM for the Chinese yuan is equal to zero because the test statistic is more than the critical value. Hence, we can proceed to Stage 2. In the second stage, we see that the null hypothesis that the rank of the matrix is less than or equal to zero as the test statistic is less than the critical value. Therefore, it can be concluded that, in the case of the Chinese yuan, the spot and forward rates have the order of integration $I(1)$ and are cointegrated.

Thereafter, we look at the case of the Indian rupee. We fail to reject the null hypothesis that the rank of the matrix of VECM for India is equal to zero because the test statistic is less than the critical value. Hence, we do not proceed to Stage 2 and conclude that the spot and forward rates of India have the order of integration $I(1)$ but are not cointegrated.

Next, we look at the Russian ruble as we reject the null hypothesis that the rank of the matrix of VECM for the Russian ruble is equal to zero because the test statistic is more than the critical value. Hence, we can proceed to Stage 2. In the second stage, we observe that the null hypothesis that the rank of the matrix is less than or equal to
zero as the test statistic is less than the critical value. Therefore, it can be concluded that the Russian spot and forward rates have the order of integration $I(1)$ and are cointegrated.

Lastly, we look at the South African case. We fail to reject the null hypothesis that the rank of the matrix of VECM for the South African rand is equal to zero because the test statistic is less than the critical value. Hence, we do not proceed to Stage 2 and conclude that the South African spot and forward have the order of integration $I(1)$ but are not cointegrated.

In summary, we can claim that based on this study of the spot and forward rates of the BRICS countries, all of the countries have $I(1)$ as their order of integration. The spot and forward rates of Brazil, China and Russia are cointegrated. However, the same variables for India and South Africa are not cointegrated.
Johansen's Test for cointegration for the bivariate VAR models of spot and forward rates of the BRICS countries

<table>
<thead>
<tr>
<th>Currency</th>
<th>Maximal Eigenvalue</th>
<th></th>
<th>Trace</th>
<th>Stage 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stage 1</td>
<td>Stage 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$H_0: r_0 = 0$</td>
<td>$H_0: r_0 \leq 1$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Test statistic</td>
<td>Critical Value</td>
<td>Test statistic</td>
<td>Critical Value</td>
<td></td>
</tr>
<tr>
<td>Brazilian real</td>
<td>55.097</td>
<td>15.670</td>
<td>1.08</td>
<td>9.240</td>
<td></td>
</tr>
</tbody>
</table>

Note: Both the maximal eigenvalue statistic and the trace statistic have been provided in this table. The procedure to determine the cointegration is as follows: In stage 1, if the null hypothesis is accepted, this means that the series have an order of integration $I(1)$ and they are not cointegrated. The testing of cointegration can be stopped here. Otherwise, if the null hypothesis is rejected, we proceed to stage 2. In the second stage, if the null hypothesis is accepted, this means that the series have an order of integration $I(1)$ and they are cointegrated. If the null hypothesis is rejected, then the series have an order integration $I(0)$. 
Table 9 below summarizes the behavior of the residuals of the bivariate VAR models which consisted of the rate of depreciation and the forward premium. We show the behavior of the residuals instead of presenting the coefficients because there are numerous variables in the VAR models. Logarithmic transformations were taken into consideration. As previously mentioned, the lag order is determined by Akaike’s information criteria.

The Portmanteau test was used for serial correlation among the residuals for multivariate time series models. It can be observed from the table that all currencies, except for the South African rand, do not have significant values for the Portmanteau test. This means that we fail to reject the null hypothesis of no serial correlation among the residuals. However, we reject the null hypothesis in the case of the South African rand. Therefore, it can be concluded that there is no sign of serial correlation present for the Brazilian real, the Chinese yuan, the Indian rupee and the Russian ruble in these VAR models but the residuals of the South African VAR model show that the serial correlation is present.

Secondly, we look at the multivariate Jarque-Bera normality test for the residuals. It can be observed that the test statistics for all the countries are significant which means that we reject the null hypothesis of the residuals following a normal distribution at 0.1% significance level. Thus, it can be concluded that the residuals of the bivariate VAR models for the rate of depreciation and the forward premium for all the BRICS countries do not follow normal distribution.

Finally, we look at the test statistic for the autoregressive conditional heteroskedasticity (ARCH). Except for the Brazilian real, all other countries have significant test statistics where the null hypothesis of ARCH models are not present is reject at a certain level of significance. The Indian rupee, the Russian ruble and the South African rand are rejected at 0.1% level of significance, whilst, the Chinese yuan is rejected at 5% level of significance. We fail to reject the null hypothesis in Brazil’s case. Therefore, we can conclude that ARCH is not present in the bivariate VAR model for the Brazilian real but ARCH is present for all other currencies.
In order to study the residuals of these bivariate VAR models visually, Figure 6 provides an illustration to appreciate the behavior of both the rate of depreciation and the forward premium and their residuals. It can be observed that the rate of depreciation and the forward premium have been closely estimated by the bivariate VAR model. The corresponding residuals of these variables are stationary. However, they behave slightly differently as compared to the residual of the spot and forward rates. In this case, there are spikes generating in the Brazilian and Russian forward premium. The reason behind this phenomenon has not been identified.

Furthermore, the graphs of autocorrelation as well as the partial autocorrelation are also given. Just like in the case of spot and forward rates, in the ACF of the residuals, we can notice that the lag order of zero is significant in all the variables for all the countries. Similarly, the partial autocorrelation of the residuals is not significant as they have not crossed the blue dotted line in the PACF graphs in Figure 6.
<table>
<thead>
<tr>
<th>Currency</th>
<th>Lag order</th>
<th>Portmanteau t-statistic (p-value)</th>
<th>Multivariate JB t-statistic (p-value)</th>
<th>Multivariate ARCH t-statistic (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazilian real</td>
<td>7</td>
<td>27.802 (0.834)</td>
<td>75670*** (0.000)</td>
<td>33.553 (0.895)</td>
</tr>
<tr>
<td>Chinese yuan</td>
<td>7</td>
<td>31.755 (0.671)</td>
<td>141.12*** (0.000)</td>
<td>75.637* (0.003)</td>
</tr>
<tr>
<td>Indian rupee</td>
<td>10</td>
<td>34.641 (0.074)</td>
<td>63.006*** (0.000)</td>
<td>92.627*** (0.000)</td>
</tr>
<tr>
<td>Russian ruble</td>
<td>5</td>
<td>47.167 (0.344)</td>
<td>34522*** (0.000)</td>
<td>140.85*** (0.000)</td>
</tr>
<tr>
<td>South African rand</td>
<td>7</td>
<td>58.306* (0.011)</td>
<td>79.345*** (0.000)</td>
<td>122*** (0.000)</td>
</tr>
</tbody>
</table>

Note: The lag order is determined based on Akaike’s information criteria. The Portmanteau test is used for serial correlation. The p-values are bold to represent that the significance of the coefficients. * = 0.05 level of significance, ** = 0.01 level of significance, and *** = 0.001 level of significance.
Figure 6 Residuals of the bivariate VAR models for the rate of depreciation and the forward premium of the BRICS countries
Table 10 shows the results of the Johansen cointegration tests. The bivariate VAR models were converted to VECM in order to check the ranks of the matrices. The test statistics for both the maximal eigenvalue test and the trace test has been provided. There are slight differences in the test statistics but the conclusion is equivalent for both the methods. Therefore, the analysis will be done once for each country.

We reject the null hypothesis that the rank of the matrix of VECM for the Brazilian real is equal to zero because the test statistic (for both maximal eigenvalue and trace) is more than the critical value in Stage 1. Therefore, we can proceed to Stage 2. In the second stage, we see that the null hypothesis that the rank of the matrix is more than zero as the test statistic is more than the critical value. Therefore, it can be concluded that, in the case of Brazil, the rate of depreciation and the forward premium have the order of integration $I(0)$.

Secondly, we fail to reject the null hypothesis that the rank of the matrix of VECM for the Chinese yuan is equal to zero because the test statistic is less than the critical value. Hence, we do not proceed to Stage 2 and we conclude that in the case of China, the rate of depreciation and the forward premium have the order of integration $I(1)$ and are not cointegrated.

Thereafter, we look at the case of the Indian rupee. We reject the null hypothesis that the rank of the matrix of VECM for the Indian rupee is equal to zero because the test statistic is more than the critical value. Hence, we can proceed to Stage 2. In the second stage, we see that the null hypothesis that the rank of the matrix is less than or equal to zero as the test statistic is less than the critical value. Therefore, it can be concluded that, in the case of India, the rate of depreciation and the forward premium have the order of integration $I(1)$ and are cointegrated.

Next, we look at the Russian ruble as we reject the null hypothesis that the rank of the matrix of VECM for the Russian ruble is equal to zero because the test statistic, is more than the critical value. Hence, we can proceed to Stage 2. In the second stage, we see that the null hypothesis that the rank of the matrix is more than zero as the test statistic is slightly more than the critical value. Therefore, it can be concluded
that the rate of depreciation and the forward premium for Russia have the order of integration $I(0)$.

Lastly, we look at the South African case. We reject the null hypothesis that the rank of the matrix of VECM for the South African rand is equal to zero because the test statistic is more than the critical value. Hence, we can proceed to Stage 2. In the second stage, we see that the null hypothesis that the rank of the matrix is less than or equal to zero as the test statistic is less than the critical value. Therefore, it can be concluded that the rate of depreciation and the forward premium for South Africa have the order of integration $I(1)$ and are cointegrated.

In summary, we can claim that based on this study of the rate of depreciation and the forward premium of the BRICS countries, no conclusion can be made for the Brazilian real and the Russian ruble whether they are cointegrated. This is because in Stage 2, both of their corresponding null hypotheses have been rejected. Secondly, we find that the rate of depreciation and the forward premium of the Indian rupee and the South African rand are cointegrated whereas, the same for the Chinese yuan are not cointegrated.
## Table 10 Johansen's Test for cointegration for the bivariate VAR models of rate of depreciation and the forward premium of the BRICS countries

<table>
<thead>
<tr>
<th>Currency</th>
<th>Maximal Eigenvalue</th>
<th></th>
<th>Trace</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stage 1</td>
<td>Stage 2</td>
<td></td>
<td>Stage 1</td>
</tr>
<tr>
<td></td>
<td>$H_0: r_0 = 0$</td>
<td>$H_0: r_0 \leq 1$</td>
<td></td>
<td>$H_0: r_0 = 0$</td>
</tr>
<tr>
<td>Test statistic</td>
<td>Critical Value</td>
<td>Test statistic</td>
<td>Critical Value</td>
<td>Test statistic</td>
</tr>
</tbody>
</table>

**Note:** Both the maximal eigenvalue statistic and the trace statistic have been provided in this table. The procedure to determine the cointegration is as follows: In stage 1, if the null hypothesis is accepted, this means that the series have an order of integration I(1) and they are not cointegrated. The testing of cointegration can be stopped here. Otherwise, if the null hypothesis is rejected, we proceed to stage 2. In the second stage, if the null hypothesis is accepted, this means that the series have an order of integration I(1) and they are cointegrated. If the null hypothesis is rejected, then the series have an order integration I(0).
5 CONCLUSIONS

In this final chapter, further discussion is made on the analysis represented in the previous chapter. The research question will be answered and the limitations of this study will be explained.

In order to test the efficiency of the emerging economies, we had formulated three research questions that we had to answer with the BRICS countries as our target countries. We first started out with testing whether the UIP condition holds. This was tested by examining whether the difference between the spot rate at time $t + 3$ and the current spot rate was explained by the interest rate differential between the foreign country in question and the domestic country. In this study, we took the US dollar to be our base currency and therefore, the three-month Treasury bill was the interest rate that represented the interest rate in the domestic country. We found that the UIP condition does not hold for any of the currencies for the BRICS countries.

Thereafter, we examined whether the unbiased forward rate hypothesis and the rational expectations hypothesis hold for the emerging economies. This was carried out by testing whether the three-month forward rate explains the spot rate three months from now. The UFH is concerned whether the forward rate is an unbiased predictor of the spot rate three months from now, whereas, the REH is concerned whether the forward rate is equal to the spot rate three months from now. If the REH holds, then this means that all information available in the market is reflected in the prices. Both of the hypothesis can be tested with the same linear regression model. In this study, this was presented in Table 6. Based on our study, we find that both of these hypotheses do not hold for any of the BRICS countries. This means that the forward rate is not an unbiased predictor of the corresponding spot rate at time $t + 3$.

To reiterate, we can say that the foreign exchange markets of the BRICS countries are not efficient. If an investor makes a forward contract for three months in the present, that forward rate is not going to be equivalent to the spot rate three months from now.

In order for us to be certain with the efficiency of the BRICS foreign exchange markets, we had performed additional tests. We looked at the behavior of the spot
and the forward rates of the countries and examined whether they were cointegrated. We found that these rates are cointegrated for the Brazilian real, the Chinese yuan and the Russian ruble. However, the rates for the Indian rupee and the South African rand were not cointegrated.

The test of cointegration for the spot and forward rates does not conclude whether the efficient market hypothesis (EMH) holds. For further examination, we carried out the same procedure for the test of cointegration for the rate of depreciation and the forward premium for all the target countries. Thereafter, we find that we cannot come to conclusion whether the variables of Brazil and Russia are cointegrated. The variables for India and South Africa are cointegrated and the same for the Chinese yuan are not cointegrated.

If the rate of depreciation and the forward premium are cointegrated, then we can confirm that the market efficiency has been violated since it implies predictability of the rate of depreciation and the forward premium. There is a long-term relationship present between the variables. Therefore, we reject the weak form as well as the semi-strong form of the EMH and we can conclude that using the Johansen cointegration test, foreign exchange markets of India and South Africa are inefficient for the period starting from 31st March 2004 to 30th April 2018.

Similarly, we find that using the same test, the rate of depreciation and the forward premium for the Chinese yuan are not cointegrated. This means that there is no long-term relationship among the variables in this case. In other words, they do not imply predictability and therefore, we fail to reject the weak form as well as the semi-strong form of the EMH and thus, conclude that for the same time period, the Chinese foreign exchange market is efficient.

As far as the Brazilian and Russian foreign exchange markets are concerned, we can claim that, just like the foreign exchange markets of India and South Africa, they are inefficient because firstly, the UIP condition does not hold for them and secondly, the UFH also does not hold.
It is also important to note that with all the three hypotheses stated in this research, we could choose the results from testing either of them to determine the efficiency of the foreign exchange markets. The Johansen test of cointegration is appropriate for testing the weak and semi-strong form of the EMH. However, testing whether the forward rate is an unbiased predictor of corresponding spot rate at time $t + 3$ is also essential. This test helps an investor to understand whether the spot rate three months from now will be worth as much as the forward contract that is entered in the present.

5.1 Limitations

This study is limited to several factors. The limitations can be avoided if more resources as well as data were available. Each of the drawbacks are discussed in this section of the chapter.

Firstly, it is assumed that the investors are all risk neutral and rational. This might not be true in practicality since the risk-appetite in the financial markets varies from investor to investor. Moreover, the rationality of investors can be a concern because many investors might not/are not willing to take rational decisions in the financial markets.

Secondly, transaction costs in UIP and CIP conditions were not considered. One reason for this was because of the lack of availability of the data in each of the foreign exchange markets. Furthermore, we have assumed that there are no taxes involved on the capital transfers and there is perfect capital mobility from one country to another.

Thirdly, the risk premia were not considered in this research. The addition of risk premia into the study would have given further insight and a better perspective. However, this would require complex econometric tools and that would go beyond the scope of this research.

Finally, we also should appreciate the drawbacks that VAR($p$) models entail. VAR($p$) models are not theoretical. Despite of using the AIC for determining the lag order, there are many tests that can be used for choosing the appropriate lag length.
Sometimes, these tests might provide us with different results and that makes the decision of choosing the optimal lag order for a VAR model difficult. Also, the parameters for these models increase with the order of the lag. Therefore, it becomes complex to produce them in a table. Hence, the behavior of the residuals was presented in this study instead for the bivariate models. Also, interpreting the coefficients of the parameters is seen as rather demanding.
REFERENCES


APPENDICES

Appendix 1 - Results of the ADF test

Table 11 ADF tests for the spot rates for BRICS countries

<table>
<thead>
<tr>
<th>BRICS currencies</th>
<th>Before differentiation</th>
<th>After differentiation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test Statistic</td>
<td>p-value</td>
</tr>
<tr>
<td>Brazilian real</td>
<td>-2.291</td>
<td>0.455</td>
</tr>
<tr>
<td>Chinese yuan</td>
<td>-1.635</td>
<td>0.729</td>
</tr>
<tr>
<td>India rupee</td>
<td>-2.865</td>
<td>0.215</td>
</tr>
<tr>
<td>Russian ruble</td>
<td>-2.122</td>
<td>0.525</td>
</tr>
<tr>
<td>South African rand</td>
<td>-2.375</td>
<td>0.419</td>
</tr>
</tbody>
</table>

Note: The ADF tests were rejected at 5% level of significance. It is important to notice that the Chinese yuan had to be differenced twice in order to make it stationary. Hence it has an order of integration of I(2).

Table 12 ADF tests for the 3-month forward rates for BRICS countries

<table>
<thead>
<tr>
<th>BRICS currencies</th>
<th>Before differentiation</th>
<th>After differentiation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test Statistic</td>
<td>p-value</td>
</tr>
<tr>
<td>Brazilian real</td>
<td>-2.386</td>
<td>0.415</td>
</tr>
<tr>
<td>Chinese yuan</td>
<td>-1.684</td>
<td>0.708</td>
</tr>
<tr>
<td>India rupee</td>
<td>-2.963</td>
<td>0.174</td>
</tr>
<tr>
<td>Russian ruble</td>
<td>-2.229</td>
<td>0.481</td>
</tr>
<tr>
<td>South African rand</td>
<td>-2.383</td>
<td>0.416</td>
</tr>
</tbody>
</table>

Note: The ADF tests were rejected at 5% level of significance.
# Appendix 2 - List of R Packages used

<table>
<thead>
<tr>
<th>Package</th>
<th>Source</th>
</tr>
</thead>
</table>

**Note:** The table lists all the R packages used in alphabetical order.