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TOPIC:

EFFICIENCY OF EMERGING FOREX MARKETS DURING THE AMERICAN AND EUROPEAN QUANTITATIVE EASING PERIODS.

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Darion Stevens

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I am thankful to my family for their support throughout compiling this research report. My Wife, Father, Mother and Brother, who are the beauty, substance and colour in my life.

Abstract

This research report investigated the efficiency of BRICS country foreign exchange markets during the American and European Quantitative Easing (QE) Periods. Market efficiency tests included autocorrelation, unit root, variance ratio, co-integration, and uncovered interest parity (UIP) testing. UIP tests indicated that the currency pairs investigated are not strong form efficient and that market efficiency diminished for US cross pairs during QE. The research also highlights changes in efficiency state prior to and post QE for the cross-pairs studied.

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Efficiency of Emerging Foreign Exchange Markets during the American and European Quantitative Easing Periods

1. Introduction

Money represents purchasing power. Money is held as a store of value, is also used as a means of exchange, and underpins collateral ownings on debt contracts (Eun & Resnick, 2009). In order to purchase goods or services in the home country, one must hold the domestic currency. In order to purchase goods in another currency, the domestic currency must be exchanged for the foreign currency. Thus, domestic purchasing power is exchanged for foreign purchasing power. This process gives rise to the foreign exchange (FX) market.

The market in which one currency is traded against another is known as the foreign exchange or forex market. It is also the world's largest market by daily turnover. In 2010, the average global forex market daily turnover was USD 4 trillion. This is 10 to 15 times larger than daily fixed income turnover and 50 times larger than daily equity market turnover. Daily turnover in 2016 was estimated at 5.1 trillion U.S. Dollars (BIS, 2016). The high turnover is attributable to hedging activity of corporations, internationally diversified portfolios, trading between hedge funds and banks, insurance companies and mutual funds. Additionally, bank deposits of foreign currency, extension of credit in foreign currency, foreign trade financing, trading in foreign currency swaps, options, and futures. Daily turnover is expected to be USD 10 trillion by 2020 (CFA Institute, 2019).

Due to increased market participation, participants range from multi-billion-dollar hedge funds, to commercial banks and retail traders. Commercial banks participate in the forex market via the

inter-bank market while retail traders or corporate banks gain access through brokerage firms which facilitate smaller transaction volumes.

Broader financial markets such as equity and fixed income markets are connected through the FX market. The trade of goods between countries would also not be possible if not for the forex market. Financial markets are greatly influenced by global news phenomenon and are transnational. This influences trade processes, production processes, net capital flows and investment portfolio performance (CFA Institute, 2019). Financial assets which make up investment portfolios are priced according to interest rate expectations and the discounting of cash flows which may be derived from these assets in the form of dividends from equities or coupon payments from bonds. Interest rates in, for example, South Africa, are influenced heavily by its trading partners such as the United States. The transnational macroeconomic factors which filter through financial markets are reflected in the forex markets.

Interbank traders who trade bilateral currency exchange rate pairs base their speculative trade decisions on the work done by thousands of analysts conducting research on market trends, price movements and macroeconomic factors such as interest rates and expected future spot rates in the hopes of forecasting future price movements (Levich, 1989). This brings into question whether exchange rates reflect the fair value of the currency or whether the trading decisions of interbank traders influence bilateral exchange rate market movements.

This research aims to focus on testing forex market efficiency of emerging markets during the United States and European quantitative easing periods.

1.1. Structure of the FX Market

Spot and forward forex (FX) markets are classified as over the counter (OTC). Market participants are connected to bank traders, brokers and non-bank traders via internet connected terminals, telephones, and automated dealing systems. There is not a single geographical location only where dealers and buyers congregate to exchange (Eun & Resnick, 2009).

The FX market is a two-tier market. The first tier consists of the interbank or wholesale market, while the second tier is the retail market. FX market participants can be filtered into 5 broad categories; central banks, FX brokers, international banks, bank customers and non-bank dealers (Eun & Resnick, 2009).

International banks conduct market making activity. Market making activity is when they are willing to buy and sell FX to generate a profit via a spread per trade. The spread being the difference between the bid and offer price on a currency cross pair. There are between 100 and 200 international banks worldwide willing to act as market makers (Eun & Resnick, 2009).

Nonbank dealers create their own dealing rooms to participate in the interbank FX market, owing to the large volume of their trades. Nonbank dealers include investment banks, mutual funds, pension funds and hedge funds. In 2007 nonbank dealers accounted for 40 percent of interbank trading volume (Eun & Resnick, 2009). The majority of interbank trades consist of arbitrage and speculative activity. Speculative activity can be described as the process in which interbank traders attempt to correctly determine the direction of future exchange spot rate movements in one currency versus another. Theoretically if no arbitrage opportunities exist; interbank traders would be unprofitable in their speculative activity. Interbank trading and speculative activity constitute a large volume of the FX market. If speculative activity is unprofitable then theoretically it should be almost non-existent. A possibility as to the source of profits potentially made by interbank

speculative activity could be a result of access to costly information. Information which cannot be easily be accessed by retail market participants. This may suggest an element of market inefficiency in the FX market.

Bank customers on the other hand purchase FX to invest in foreign assets. Bank customers include private speculators, multinational corporations, and money managers. BIS statistics in 2007 showed that retail transactions account for 17 percent of FX trading volume. The remaining 83 percent in volume relates to interbank trades between international banks (Eun & Resnick, 2009).

FX brokers match buy and sell dealer orders for a fee but do not take a position in the currency market themselves.

1.2. Context of the Study

The United States Central Bank made use of unconventional monetary policy following the 2008 financial crisis, namely through quantitative easing (QE). The Federal Reserve Bank has the ability to print an unlimited amount of money in order to acquire assets. These assets include government bills, asset backed securities or assets issued by the private sector. This expanded the size of the Federal Reserve's balance sheet. The Federal Reserve's balance sheet grew through the purchase of sub-prime mortgage debt and collateralized debt obligations. These greater assets would be matched by liabilities in the form of greater reserves held by commercial banks and more Dollar currency in circulation (Joyce, Miles, Scott & Vayanos, 2012).

The Federal Reserve's purchasing of assets led to a low interest rate environment. The purchasing of assets such as asset backed securities and bonds resulted in the price of these fixed income securities increasing. As a result, the related yield on these instruments declined. There is an inversely proportional relationship between interest rates or bond yields and the price of fixed

income securities such as bonds. As the price of fixed income securities increased and the size of the Federal Reserve's balance sheet grew, interest rates began to decline. This created a low interest rate environment. A low interest rate environment would in theory encourage economic growth as the cost of capital for corporate firms would reduce, making new investments by firms through debt financing cheaper. Theoretically, a low interest environment would encourage consumer spending as credit became cheaper. However, this must be matched with good sentiment by consumers regarding the economic outlook to encourage spending.

Quantitative easing produced more currency in circulation and increased the amount of cash held by commercial banks. The low interest rate environment in the United States resulted in capital flows into emerging markets, as U.S. investors sought higher interest rates and yields. If currency markets are efficient, theoretically no arbitrage conditions would exist prior to the financial crisis and no arbitrage conditions would exist after the U.S. housing bubble collapse of 2008. Currency exchange rates should follow a random walk before the financial crises as well as after it. This research seeks to investigate whether Dollar related exchange rates in currency markets efficiently priced in quantitative easing. Theoretically, quantitative easing should not have created arbitrage opportunities if currency markets were truly efficient. This would imply that exchange rate time series data followed a random walk before the financial crisis as well as after it. This research seeks to investigate evidence of market efficiency in U.S. Dollar exchange rates in light of unconventional monetary policy techniques employed by the United States Central Bank.

During the 2008 financial crisis, the United States Central Bank purchased asset-backed securities and collateralized debt obligations (CDOs) underpinned largely by subprime mortgage debt. The Federal Reserve printed U.S. Dollars to do so. This printed money was used by the Federal Reserve to purchase CDOs and asset backed securities from U.S. investment banks. This monetary stimulus

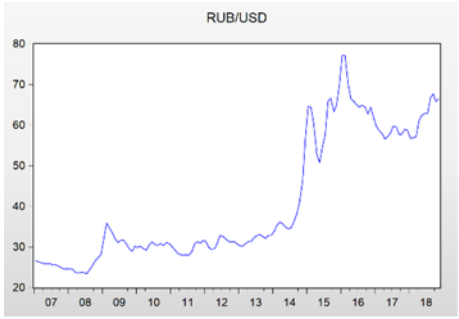
reduced interest rates to stimulate GDP growth. The U.S. central bank's balance sheet grew from $900 billion prior to the financial crisis, to $4.5 trillion in 2015 (Economist, 2017). Financial assets which were purchased using newly created bank reserves.

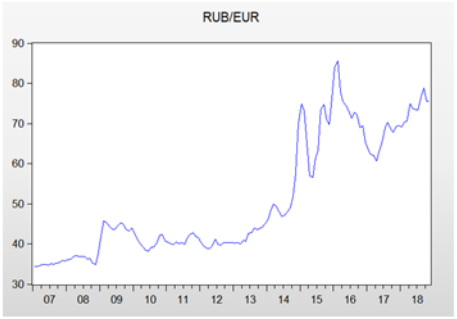
The European Central Bank (ECB) also undertook quantitative easing. The 2004-2007 period was a boom period in money and credit growth with a stable growth and inflation outlook. However, the U.S. financial crisis and the European zone sovereign debt crisis resulted in the double dip recession of the period 2008 to 2013, followed by the 2014 to 2017 low inflation recovery period (Hartmann & Smets, 2018). The ECB's approach was to stabilize the short-term interest and protect the European real economy. The ECB dropped its main policy rate to 1% due to a drop in output and trade and carried out its Covered Bonds Purchasing Programme (CBPP), the aim being to provide banks with required liquidity and to support their ability for credit intermediation (Hartmann & Smets, 2018). The ECB's asset purchasing program which bought roughly $2.9 trillion worth of securities and assets, started in 2015 and was announced to end in December 2018.

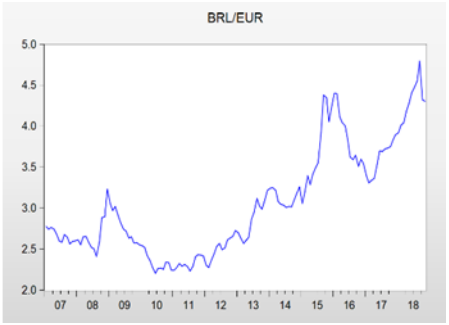
At the end of 2017, the Federal Reserve signaled that it would begin shrinking its balance sheet. Intervention within the FX market on such a large scale may or may not affect weak form efficiency of the FX market. Literature suggests that there is little evidence that massive intervention in the FX market materially affects exchange rates (Eun & Resnick, 2009).

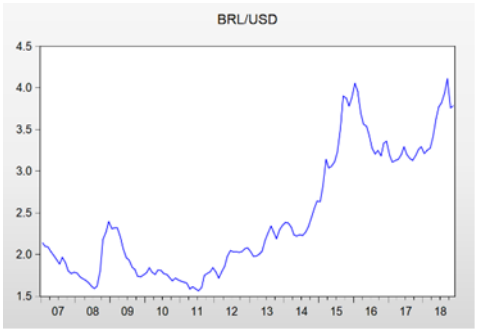
Plots of the monthly average exchange rates for emerging market currencies against the Euro and U.S. Dollar suggest that the currency pairs are trending over time and are not mean reverting. The currency pairs plotted include the ZAR/USD, ZAR/EUR, BRL/USD, BRL/EUR, INR/USD, INR/EUR, RUB/USD, RUB/EUR, CNY/USD and CNY/EUR. That is the emerging market currencies of South Africa, Brazil, India, Russia and China.

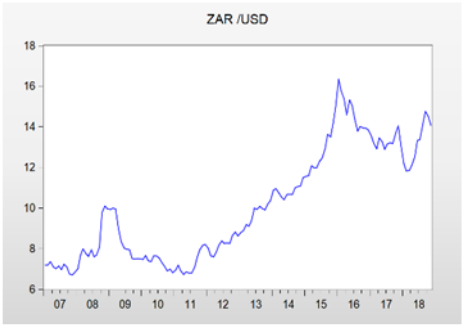
The fact that these plots appear to show recognizable upward trending pattern over the period 2007 to 2018 warrants further investigation.

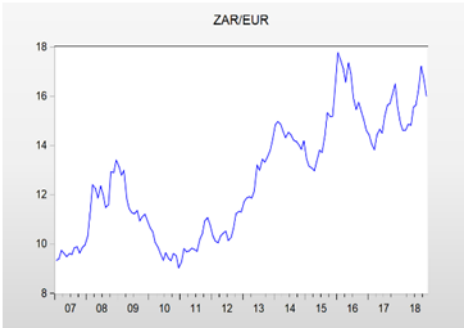




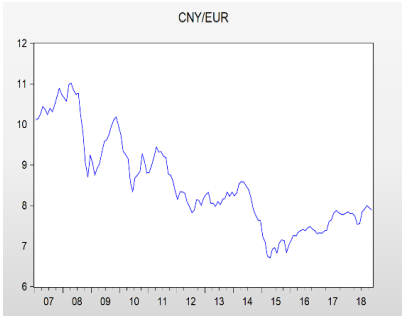


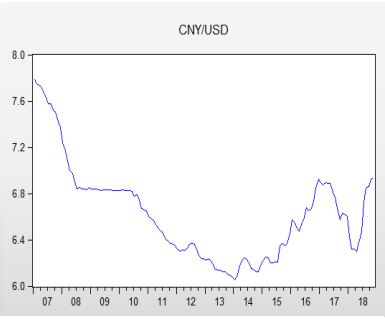


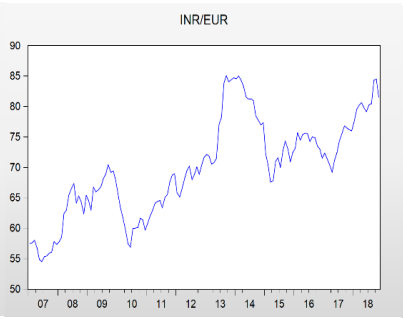


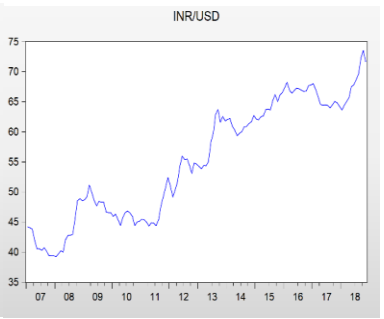


The plots specifically relate to BRICS countries and forex market efficiency was investigated for these countries.









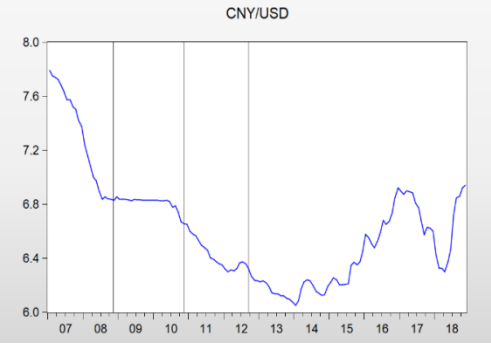
2. Background Preliminary Analysis

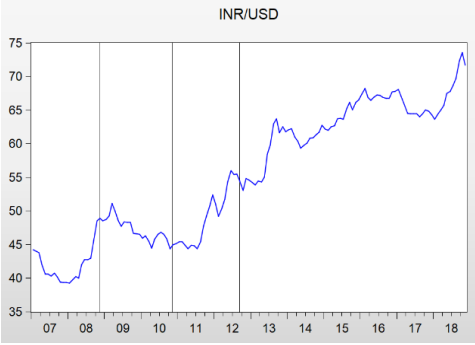
2.1. U.S Quantitative Easing

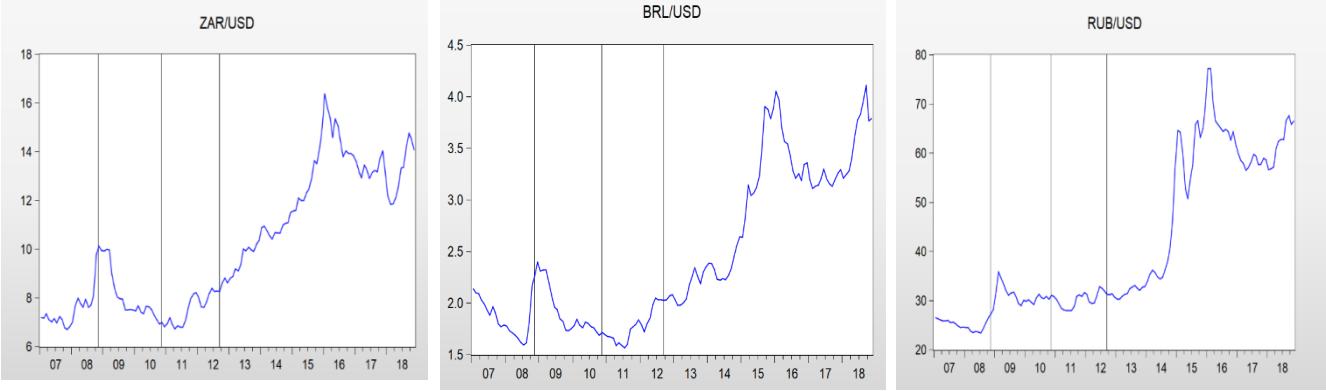
U.S Quantitative Easing 1 (QE1) was initiated in November 2008 and lasted until March 2010. QE2 ran from November 2010 until June 2011 (Maggio, Kermani & Palmer, 2016). In September 2011 the U.S Federal Reserve began the Maturity Extension Program (MEP), also known as

Operation Twist. The Federal Reserve sold shorter term treasury securities and purchased longer term securities, increasing the price of longer term securities and reducing the yield on these instruments. The opposite held true for the short term treasury securities, resulting in an increase in short term yields. QE3 was announced on September 2012. The Fed chairman at the time, Ben Bernanke announced tapering of the Fed's asset backed mortgage securities to on 22 May 2013 (Maggio, Kermani & Palmer, 2016). It can therefore be assumed tapering began in June 2013. The Federal Reserve officially began unwinding QE and its balance sheet in October 2017.

An analysis of each currency pair's trajectory was done. The event of interest are the quantitative easing periods. The solid vertical lines indicate the month in which quantitative easing was initiated. QE1, QE2 and QE3 initiation dates are represented by the vertical lines in succession from left to right. Any change in direction of the price direction after QE initiation would suggest non-random price behavior and would warrant an investigation into the state of change in market efficiency.



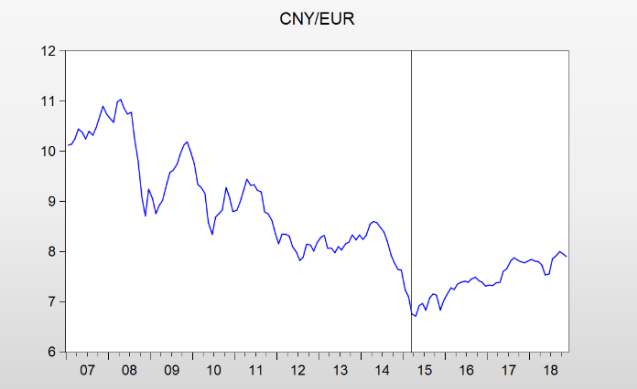


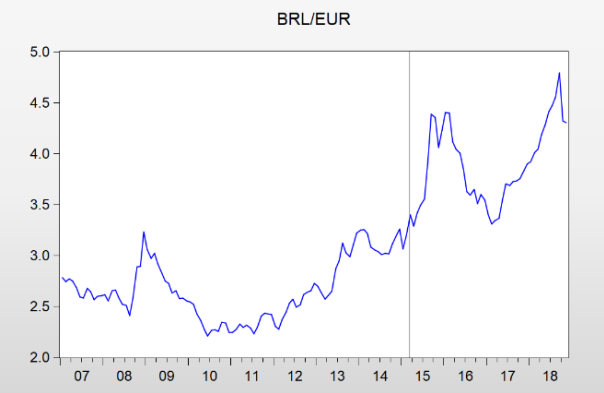


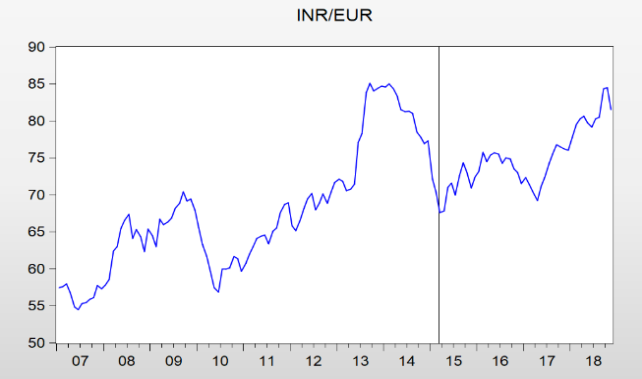
The ZAR/USD and BRL/USD pairs show price direction changes following QE1 and QE2. The INR/USD pair shows a price direction change after QE1, QE2 and a short down trend for roughly 10 months after QE3 before continuing in an upward direction. The RUB/USD pair shows a price change direction after QE1 when considering the downward price direction from January 2007, through to the third quarter of 2008. After QE1, an upward trend in the RUB/USD can be seen. Limited change in price direction could be seen for the CNY/USD after QE1, QE2 and QE3.

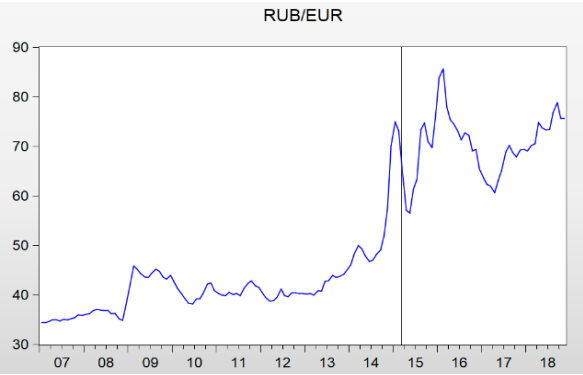
2.2. European Quantitative Easing

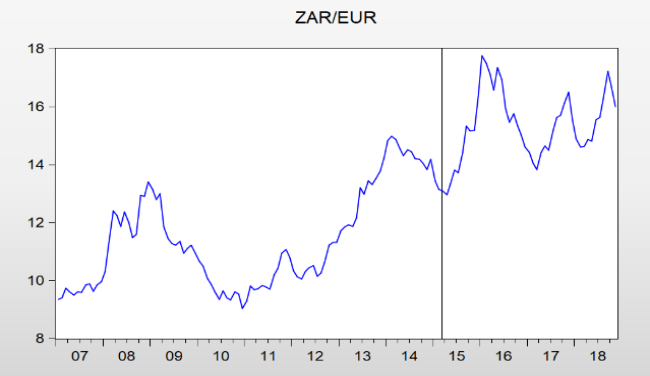
Quantitative easing was launched by the European Central Bank (ECB) on March 2015 (Reuters, 2018). The asset purchasing program was initiated to prevent sub-zero inflation in an attempt to bolster an economy still suffering from the Euro-Zone debt crisis. The ECB spent $3 trillion over four years, purchasing government debt, corporate debt, asset-backed securities, and covered bonds at €1.3 million per minute (Reuters, 2018). Quantitative easing by the ECB was officially tapered in December 2018. QE1 administered and initiated by the ECB is represented by the solid vertical line (March 2015).











The CNY/EUR, INR/EUR and ZAR/EUR currency pairs show a clear directional price change upon initiation of quantitative easing by the ECB in March 2015. The BRL/EUR and RUB/EUR do not show directional price changes; however, the currency pairs do appear to be trending directionally.

2.3. Correlograms

A random walk variable is of the form $P_t = \propto + P_{t-1} + \varepsilon$ and the randomness of the time series can be evaluated by determining to what degree a previous price determines the future price in the series. The autocorrelation of the series describes how correlated or related one price point is to another one period away. The autocorrelation function (ACF) plot displays a histogram representing the coefficients of correlation per lag of the time series. The partial autocorrelation function (PACF), is a plot of partial correlations between a time series and lags of the time series. A partial correlation can be described as the correlation existing between 2 data points not explained by their mutual correlations with other variables in the data set (Duke, 2019). The correlograms illustrate the ACF and PACF plots for the currency pairs concerned.

The magnitude of the autocorrelation coefficients increased during U.S QE1, versus a year prior to it, for the ZAR/USD, INR/USD and BRL/USD ACF plots, especially when considering the first 4 lags. Suggesting that correlation between monthly data points increased for these currency pairs. This, however, did not hold true for the CNY/USD a RUB/USD currency pairs. The correlograms can be seen in Appendices A1 to A10.

When considering ECB quantitative easing, the ZAR/EUR, CNY/EUR, INR/EUR, BRL/EUR and RUB/EUR show faster decaying and reduced autocorrelation after the European quantitative easing which was initiated in March 2015. The correlograms can be seen in Appendices B1 to B10.

3. Problem Statement

This research seeks to investigate whether quantitative easing by the U.S. and Europe resulted in inefficiencies in the forex market, in the context of developed versus developing country bilateral

exchange rates. If the forex markets follow random walks, it is assumed that they are weak form efficient and quantitative easing did not contribute to inefficiencies in the market. The developed market currencies refer to the Euro and the U.S. Dollar. The developing market currencies are those belonging to the BRICS bloc. Studies of forex markets have tended to ignore the effects of quantitative easing on market efficiency.

Developing markets such as South Africa are resource exporting countries and inefficiencies in the exchange rate may result in excess volatility especially when the currencies are free floating. This may negatively or positively impact trade. Some studies have examined forex market efficiency in developing countries (Engelbrecht, Mabakeng, Peyavali & Sheefeni, 2014 for Namibia; Aron, 1997 for South Africa; Sasikumar, 2011 for India and Mukherjee, 2018 for BRICS countries).

These studies report mixed findings. However, they do not fully cover the U.S. (2008-2017) and European (2015-2018) quantitative easing periods. For instance, using the Johansen cointegration procedure, Mukherjee (2018) finds that the random walk hypothesis does not hold for BRICS country monthly exchange rate data against the United States Dollar. The study does not cover the Euro, in addition to not covering the entire quantitative easing period.

This study attempts to address this omission in the literature by covering all the quantitative easing episodes and pairs of BRICS currencies with the two currencies of the countries/regions engaging in quantitative easing – the US dollar and the Euro. This study investigates whether U.S. and European quantitative easing changed market efficiency state. Therefore, tests of the state of market efficiency are done for a period before the respective quantitative easing periods as a control test and be contrasted against findings during the quantitative easing period.

4. Research Objectives

The research objectives of this study are as follows:

1) Investigate the state of market efficiency of the BRICS currency cross pairs against the U.S. dollar and the euro prior to, during and post the U.S. and European quantitative easing periods.
2) Ascertain the impact of U.S. and European quantitative easing on BRICS currency cross pairs when considering forex market efficiency.
3) Record any changes to foreign exchange market efficiency, prior to, during and post U.S. and European quantitative easing periods.

5. Research Questions to be Answered or Hypotheses

1) What is the state of market efficiency of BRICS countries' currencies versus the U.S. Dollar and the Euro prior to, during and post quantitative easing, when considering the U.S and European quantitative easing periods?
2) Are there any changes in the state of forex market efficiency for the BRICS countries' currencies versus the U.S. Dollar and the Euro prior to, during and post the U.S. and European quantitative easing periods?

6. Hypothesis Statement

The hypothesis statement for this study is as follows:

H_0: Quantitative easing did not coincide with a change in the state of foreign exchange market efficiency.

H_1: Quantitative easing coincided with a change in foreign exchange market efficiency state.

7. Significance of this Study

Market efficiency is of importance for developing countries owing to their susceptibility to harsh shocks in the context of the global economy (Katusiime, Shamsuddin & Agbola, 2014). For example, during global economic crisis and economic downturns, investors sell South African Rands to purchase U.S. Dollars even though the intrinsic value of the Rand may not warrant a drastic sell off.

When considering Uganda, the global financial crisis led to excessive volatility of the exchange rate during and after the crisis. This raised concerns of market inefficiency and currency misalignments leading to currency mispricing which provides incorrect signals for resource allocation which could result in macroeconomic instability (Katusiime, Shamsuddin & Agbola, 2014). As a result, Katusiime, Shamsuddin & Agbola (2014) undertook research into investigating the efficiency of Uganda's forex market. This study was undertaken for the same reasons. Research on the forex market efficiency of BRICS countries prior, during and after the U.S. and European quantitative easing periods is limited.

8. Literature Review

8.1 Theoretical Literature Review

8.1.1 Exchange Rate Equilibrium and Determination

The exchange rate represents the price of a currency. It indicates the rate at which one currency can be exchanged for another. The price of a currency is a function of its demand relative to its supply. The equilibrium exchange rate stipulates that at any given time a currency should display a price which is consistent with the supply and demand for that currency. In time, external changes take place, for example a change in real interest rates. This change affects the supply of a given

currency and demand for it. The change in supply and demand due to the shock is reflected in the price changes of the currency affected. The price of the currency adjusts to reflect the change in say interest rates (Madura, 2013).

Demand for South African Rands would emanate from economic agents resident in countries outside of South Africa wanting to purchase South African goods and/or invest in South African assets (Crosoer,2018). Thus, the demand for South African Rands is due to international trade flows, as well as international capital flows.

If considering the U.S. as a domestic country and South Africa as foreign, the demand for Rands would increase, if the Rand becomes cheaper. If this concept was graphed, with quantity of Rands placed on the x-axis and the U.S. Dollar/Rand rate on the y-axis, as the Dollar/ Rand rate decreases, the quantity of Rands bought increases (Madura, 2013). This could be graphically depicted as a negatively sloping demand schedule line graph on the respective axes.

South African Rands can also be supplied to the foreign exchange rate market to be exchanged for Dollars. This will occur when the Rand is stronger relative to the Dollar. Therefore, the stronger the Rand relative to the Dollar, the more Rands will be supplied to the FX market to purchase Dollars. If this relationship was graphed, where the quantity of Rands supplied was placed on the x-axis and the Dollar/Rand exchange rate on the y-axis, a positive relationship would be graphed. As the Dollar/Rand rate increase, the supply of Rands to the FX market also increases. Denoting the supply schedule for the South African Rand.

The demand schedules and supply schedules for the South African Rand can be combined. The point at which the demand and supply schedules intersect, is known as the exchange rate

equilibrium position (Madura, 2013). This is a state such that the Rands demanded is precisely satisfied by the Rands supplied to the FX market.

In a case where the number of Rands exceeds those supplied for the market, a Rand shortage would exist. In the case of the number of Rands supplied exceeding those demanded, an oversupply would exist. Both cases indicating a disequilibrium state.

The change in exchange rate equilibrium can be explained by an increase in the demand schedule, decrease in the demand schedule, increase in the supply schedule, and decrease in the supply schedule (Madura, 2013).

If the demand schedule increases and shifts outwardly to the right, while the supply schedule is held constant, the demand for Rands will increase. There will be a shortage of Rands. The foreign exchange rate price will adjust. The Dollar/Rand price will increase. This adjustment will cause demand for the Rand to decrease and supply of Rands to increase to meet this new demand, establishing a new equilibrium in the process.

Considering a reduction in the demand for Rands and a downward shift in the supply schedule to the left, as the supply schedule is held constant. In this case, an oversupply of Rands will exist. Therefore, the exchange rate price of Dollar/Rand will be lowered by banks, increasing the demand for Rands, to meet the new level of supply (Madura, 2013). Establishing a new equilibrium.

An increase in the supply schedule of South African Rands will result in an oversupply of Rands. Banks will intervene and lower the price to increase demand such that supply equals demand (Madura, 2013). The opposite will occur for a decrease in the supply schedule.

8.1.2. Purchasing Power of Parity (PPP), Portfolio Balance and Monetary Models

Purchasing Power of Parity (PPP), portfolio balance and monetary models have not been tested in this report but are however mentioned briefly for completeness of the theoretical literature review.

The purchasing power of parity (PPP) exchange rate is the rate which represents one unit of purchasing power of a country in the domestic context, as well as the foreign country's economy (Pedroni, 1997). The absolute PPP is the exchange rate which would equate the two national price levels (Sarno & Taylor, 2002). Relative PPP can be described as the state achieved when the depreciation of one currency relative to another equals the difference in price inflation between the two countries of interest (Sarno & Taylor, 2002).

The nominal exchange rate is the price of one currency in terms of another. The real exchange rate is the nominal exchange rate adjusted for national price level differences (Sarno &Taylor, 2002). If PPP holds then the real exchange rate is constant, any changes in the real exchange rate implies deviations from PPP. PPP may not hold in real world conditions; however, it is believed to serve as an anchor for real exchange rates in the long run.

The monetary model determines the exchange rate based on the relative price of the currencies such that the price is based on the supply or demand for the stocks of money of the currency (James, Marsh & Sarno, 2012). The monetary model stipulates that higher income results in a stronger currency and a higher relative interest rate results in a weaker currency. A higher income in the model would imply higher money demand, relative to supply, resulting in a stronger currency. A higher interest rate results in lower money demand relative to money supply and thus a weaker currency (James, Marsh & Sarno, 2012).

The portfolio balance model can be contrasted against the monetary model because it differs slightly in that it assumes that assets denominated in different currencies cannot perfectly be substituted for one another. For example, bonds, even when denominated in the same currency, may have different risk premiums because of their geographical locations (James, Marsh & Sarno, 2012).

8.1.3. Behavioural Economics and Finance

Behavioural economists have found inconsistencies between the rational expectations theory and the ways in which humans actually do behave. The foundation of this criticism lies in the fact that humans cannot understand the complexity of the financial market interactions and the world around them. James, Marsh & Sarno (2012) present a behavioural economics-based model of the foreign exchange rate market. Based on the assumptions that individuals have limited cognitive ability in processing information, economic agents are not capable of understanding the complexities of the underlying model. Because economic agents do not fully understand this complexity, they make use of simple rules instead to make judgements. The model assumes a chartist rule and a fundamentalist rule based on the intrinsic value judgement on the exchange rate (James, Marsh & Sarno, 2012).

8.1.4. The Random Walk Hypothesis (RWH)

There are two main concepts underpinning the random walk model. Firstly, future foreign exchange spot rates are unpredictable in both long and short runs. Secondly, the variance of a sample is proportional to the sampling interval (Rashid, 2006). A random walk process implies that the variance from one data point to the next at first difference is not constant and changes with

time. The covariance between data points should also vary with time. This implies a non-stationary process and the presence of a unit root.

If future spot exchange rates are unpredictable, past spot rates cannot be used to predict future price action. This implies that the successive values of the time series are uncorrelated and contain a unit root. If spot exchange rates follow a random walk, policy makers cannot base future policy decisions on historical prices, if the objective of the policy maker is to protect the growth of the economy.

A time series of data points is found to be uncorrelated if the variance of the sample is proportional to the sampling interval (Rashid, 2006). That is, the variance of the differences between exchange rate interval data points for sampling is not constant. If the variance of a time series is linear, and non-constant, the increments are uncorrelated (Rashid, 2006). This property is important for traders wishing to understand the risk associated with exchange rate speculation. As future prices cannot be determined from past prices if the time series data points are uncorrelated.

Market efficiency suggests that a financial security reflects available information and thus the price of the instrument can be used as an indicator of how best to allocate resources for their most productive use (Fama & Litterman, 2012). To test market efficiency, one must consider how the market prices instruments. This requires a consideration of the equilibrium relationship between risk and return which in turn drives prices.

Eugene Fama stumbled onto the theory of market efficiency as an undergraduate when working for a stock forecasting service. His job was to created mechanical trading rules which correctly predicted stock price movements. Fama considered correct security price predictions in an in sample and out of sample context. His rules only worked for sample or past historical data. His

forecasts were not successful for out of sample, or as he puts it, forward data (Fama & Litterman, 2012). It then dawned on him that the reason his trading rules did not work for out of sample data, could have been because financial markets are possibly unpredictable and random. For many years thereafter researchers believed that this randomness implied an efficient market. Instead, it is suggested that market efficiency means that deviations from expected returns are unpredictable based on information available at present (Fama & Litterman, 2012).

8.1.5. Forms of Market Efficiency

A market is said to be efficient if prices in it fully reflect all available information and correctly represent the intrinsic value of securities on offer in the capital market (Fama, 1970). Semi-strong form market efficiency is concerned with the speed or rate at which publicly available information is reflected in security prices or returns. Strong form market efficiency is concerned with investigating whether any market participant has monopolistic access to information, which may affect price formation and may give the participant an edge over others.

The weak form market efficiency theory suggests that prices are independent and follow a random walk. It also proclaims that present market prices reflect all historical market prices and currently available information (Yang, Shao, Shao & Stanley, 2019). This is the focus of this research report. Hallwood and MacDonald (2000) describes an efficient FX market as follows:

- Speculators cannot make abnormal returns or profits.
- There exists no exploitable information which gives rise to arbitrage opportunities.
- FX market participants make use of all available information in such a manner that spot and forward exchange rates display historical information such that arbitrage opportunities do not exist.

- No room for government intervention exists because the FX market is fully efficient and reflects all available information.
- Covered interest parity and uncovered interest parity conditions are assumed to hold at all times.
- The forward spot exchange rate is an unbiased estimator of the future spot exchange rate.

It should be noted that arbitrage is not possible in a perfectly efficient financial market.

8.1.6. Forex Market Arbitrage

Arbitrage can be defined as taking advantage of market pricing inefficiencies to make a riskless profit. The pure definition of the concept implies that an investment of funds is not tied up for a long period of time and does not involve a high degree of risk (Madura, 2013). Market forces will intervene to realign exchange rates to their correct level if any misalignments exist. The realignment occurs because of international arbitrage. International arbitrage can take the form of locational arbitrage, triangular arbitrage or covered interest arbitrage.

Locational arbitrage describes the concept of purchasing currency where it is cheap and then selling it for a profit in another location because a price discrepancy exists between the two locations. Banks make use of telecommunications networks, computers, and technology to capitalize on price discrepancies on exchange rates at different locations at various international banks and currency exchange dealers. The use of technologies reduces the likelihood of significant discrepancies between quoted exchange rates (Madura, 2013).

Triangular arbitrage refers to arbitrage opportunities which arise when the quoted market exchange rate differs from the implied exchange rate when considering the following forward cross-exchange rate formula:

$F_N(j/k) = \frac{F_N(\$/k)}{F_N(\$/j)}$, where, for illustrative purposes, j = € and k = £

The implied forward Euro/Pound exchange rate can be determined by using the Dollar/Pound and Dollar/Euro exchange rates. Suppose that the quoted Dollar/Pound and Dollar/Euro rates result in an implied cross-exchange rate of $F_N(j/k)$, where $F_N(j/k)$, is less than the bank quoted, mispriced Euro/Pound rate; triangular arbitrage could take place.

Covered interest arbitrage is the process of generating a profit due to the interest rate differential between two countries and hedging the risk with a forward exchange rate contract (Madura, 2013). If the foreign country's interest rate is 7% per annum and the domestic interest rate is 4% per annum, one can borrow domestic funds, convert them to the foreign country's currency and deposit the funds there to earn 7% after one year. A forward exchange rate contract can be drawn up to lock in the exchange rate and remove the exchange rate risk. Arbitrage in this instance refers to realizing a larger gain offshore versus the same domestic investment.

Commonly, covered interest parity (CIP) is expressed as: $(1+i_d) = \frac{1}{s}(1+i_f)$F, where, i_d is the domestic interest rate, i_f the foreign asset bearing interest rate, s, the spot exchange rate and F, the forward exchange rate. When considering ask-bid spreads of interest and exchange rates, covered interest arbitrage is not possible under the following conditions (Akram, Rime & Sarno, 2005):

$(1+i_d^a) \geq 1 / [s^a (1+i_f^b) F^b]$

$(1+i_f^a) \geq s^b (1+i_d^b) / [F^a]$

Where, a denotes the ask rate and b denotes the bid rate. Ask rates are greater than bid rates. A trader encounters ask rates when borrowing funds and bid rates when lending (Akram, Rime &

Sarno, 2005). A trader receives the ask rate when buying a currency. When a trader sells a currency, he receives the bid rate.

As with all forms of arbitrage, market forces will nullify arbitrage opportunities because those taking advantage of arbitrage opportunities will realign markets, such that no opportunity exists. There will be pressure on the forward exchange rate as investors seek to take advantage of the covered interest arbitrage opportunity. When the discount between the forward and spot exchange rate equals the interest rate advantage differential, the arbitrage opportunity will no longer be available.

8.1.7. Anomalies in the Foreign Exchange Rate Market

Research indicates anomalies present in the foreign exchange rate market. The outcome being that it is difficult to find long term reversion to an equilibrium position. It was found that traders and speculators seldom use macroeconomic fundamentals to base their opinions (Goodhart, 1988). Instead speculation is based on proprietary models based on other factors.

Goodhart (1988) witnessed how exchange rates did not respond dramatically to changes in interest rates as he had anticipated. Especially since these innovations or shocks to the market would have been unknown disturbances introduced to the market in the form of economic news. There was also a difference between the beliefs of traders and economic theory. Economic theory suggests that due to the high volume of capital in the market, news event triggers should cause spot exchange rates to overshoot their long-term equilibrium levels and then revert towards them. Instead the forex market shows persistence, trending and inertia in the short run defined as months, days and weeks (Goodhart, 1988).

Theory also suggests that longer term exchange rates should be rooted in fundamental purchasing power of parity equilibrium forces. Instead, for the period 1973 to 1985 foreign exchange rates followed a random walk (Goodhart, 1988). Forward exchange rates were also found to provide no concrete indication of the direction of current spot rates. Speculation within the forex market is not well understood theoretically and is not based on long term fundamental views. Owing to risk aversion and uncertainty in predicting the future (Goodhart, 1988). Large volumes of speculation occur on a very short-term basis.

Surveys regarding opinion of the longer-term trend of exchange rate prices diverge more from the historical random walk path (Goodhart, 1988). There was also found to be an underreaction instead of an overaction to news affecting the forex market.

8.1.8. Arbitrage profiteering in the FX market

George Soros is famously known as the man who broke the bank of England. Soros created a trading style which centered around the concept of reflexivity. He believed that financial markets operated according to an equilibrium and that policy makers and governments made decisions which sent shocks through financial systems, pushing financial markets away from this equilibrium. Soros believed that decision makers' actions countered the natural progression of free market systems (Sether & Wasendorf, 2009). Giving rise to arbitrage opportunities when disturbances from equilibrium presented.

George Soros founded Quantum Fund and sought to put his theory into practice. On Black Wednesday, 16 September 1992, Soros used his theory to become the 27th richest person in the world at the time. The U.K. had entered the European Exchange Rate Mechanism (ERM) in 1990. During this time inflation was 3 times that of Germany's and interest rates were high. The high

inflation and interest rates led to GDP decline and an increase in unemployment. Germany had high interest rates at the time and the ERM required that the U.K. raise interest rates in line with Germany to prevent depreciation of the Pound. The U.K. government raised the base interest rate from 10% to 12% to prevent further depreciation of the currency. However, a further increase was required. Soros recognized this as an opportunity and on Black Wednesday sold short roughly £10 billion. Forcing Britain to withdraw from the ERM. Soros' trade was profitable, and it is estimated that he profited a minimum of £1 billion (Sether & Wasendorf, 2009).

8.1.9. Rigging of the Rand

In 2007 Citibank was ordered to pay a R69.5 million administrative penalty for participating in a forex cartel which rigged the ZAR/USD currency pair (Ismail, 2017). The cartel which consisted of BNP Paribas, JP Morgan, Investec, HSBC, Credit Suisse Group, Nomura International and Macquarie Bank, as well as several others, coordinated trading times, bidding up the currency pair at well-timed intervals such that the currency pair could be pushed to a desired level of profit. The cartel also created false orders which created supply and demand imbalances within the forex market for the purposes of securing profit. The volume in currency traded by investment banks, if coordinated well can move the direction of a currency pair because the wholesale forex market of which these banks constitute accounts for more than 80 percent of the forex market.

The rigging of the ZAR/USD by large investment banks suggests that the output from the forex spot generating process is not entirely random and arbitrage opportunities do exist. This implies that those seeking to benefit from these arbitrage opportunities trade alongside large investment banks when rigging activity does take place. Intuitively, access to this information is unlikely if one is not a member of the forex cartel.

8.2. Empirical Literature Review

8.2.1. The Effect of Proprietary Trading

The U.S. banking industry has fiercely defended its proprietary trading and market making activities, citing that these activities significantly contribute to the profitability of U.S. banks. Additionally, there would be significant negative consequences for investors, financial markets and the U.S. economy (King, Massoud & Song, 2013).

Bank holding companies with a higher share of trading assets to total assets in the U.S. were seen to contribute more to systemic risk. Proprietary trading was found to have adverse risk effects. From the period 2007-2012, U.S. banks with higher trading to total asset ratios displayed lower profitability and higher risk (King, Massoud & Song, 2013).

Proprietary trading in the form of algorithmic trading (AT) and its influence on market efficiency was investigated by tracking excess volatility and the frequency of triangular arbitrage opportunities (Chaboud, Chiquoine, Hjalmarsson & Vega, 2014) in the foreign exchange market. The currency pairs investigated were the EUR/USD, USD/JPY and GBP/USD. The research showed that high frequency proprietary trading resulted in a reduction in arbitrage opportunities and a reduction in excess high frequency volatility. It was found that AT traders act on the trades posted by non-algorithmic traders and in so doing reduce the number of arbitrage opportunities available. AT was found to improve informational efficiency and increase the rate of price determination.

Proprietary trading firms making use of low-latency technology can be classified as high frequency traders, where trades are placed in the capital market within a millisecond time frame. Increased low-latency activity was found to speed up the price discovery process, lower short term volatility

and decrease spreads within capital and U.S. equity markets (Hasbrouck & Saar, 2013). Similar findings may also present in foreign exchange markets.

Simple trading rules in the foreign exchange market were found to be profitable in the 1970s and 1980s (Neely & Weller, 2011). These simple profitable trading rules were used less during the 1990s and more complex trading rules have been adopted since. The profitability of trading has decreased since the 1970s (Neely & Weller, 2011). This would suggest that as market participants act on trading rules, they reduce the number of arbitrage opportunities available and contribute to making the foreign exchange market more efficient.

8.2.2. Empirical Tests of Market Efficiency

Market efficiency tests of the foreign exchange rate market began in the 1960s (Levich, 1989). With the proliferation of free-floating exchange rates in the 1970s research into market efficiency of the forex market increased. Early studies could not disprove the market efficiency hypothesis. However, abnormalities in the market were not classified as such in the research but classified as anomalies and not occurrences which disprove market efficiency. Studies have shown that foreign exchange markets have presented profit opportunities (Levich, 1989). It is however unclear whether this profit taking was due to price inefficiencies or compensation for risk. Modern financial theory states that exchange rates can be interpreted as financial assets, with current spot rates reflecting the discount to present value terms of expected external macroeconomic factors and microeconomic factors such as volume traded.

Market efficiency of BRICS bloc foreign exchange markets has been studied by investigating the uncovered interest parity (UIP) condition (Mukherjee, 2018). The UIP condition is tested by testing the relationship between the difference of the expected 3 month FX spot rate less the spot

rate at t=0, and the interest rate differential between the foreign country and the domestic country. The domestic interest rate being the U.S. 3 month treasury bill. The regression equation is as follows (Mukherjee, 2018):

$$\ln(S_{t+3}) - \ln(S_t) = \alpha + \beta\left(i_{foreign} - i_{U.S.}\right) + \varepsilon_{t+1}$$

If the UIP condition holds, the respective forex market is found to be efficient. The UIP condition is found to hold if $\alpha = 0$ and $\beta = 1$.

The augmented Dickey Fuller test is used by Mukherjee (2018) instead of the traditional Dickey Fuller test to test for unit roots. The motivation being that the augmented version can accommodate higher order autoregressive order processes in the error term.

Mukherjee (2018) also tests whether the 3 month forward rate is an unbiased estimator of the expected spot rate at time t+3, periods being months. This tests whether the unbiased forward rate hypothesis or rational expectations hypothesis holds. If the 3 month forward exchange rate is an unbiased estimator of the future spot rate at t+3, the market is found to be efficient. This is investigated by a joint null hypothesis of $H_0: \alpha = 0$; $H_0: \beta = 1$ for the linear regression equation between the 3 month forward exchange rate and the corresponding spot exchange rate at t+3. The equation is as follows (Mukherjee, 2018):

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

If the joint null hypothesis does not hold, the 3 month forward exchange rate is not an unbiased estimator of the corresponding spot exchange rate in 3 months' time.

Mukherjee (2018) makes use of a bivariate vector autoregressive (VAR) model to model the relationship between the spot and forward exchange rates. The VAR model was used because

dependent and independent variables need not be specified as all variables are assumed to be endogenous. The optimal lag order for the VAR model was selected using Akaike's Information Criteria (AIC). If the incorrect number of lags are used, the model would not be a reliable one (Mukherjee, 2018).

Vector error correction models are used by Mukherjee (2018) on the VAR to ensure the model is stationary if the VAR model is non-stationary.

The Johansen cointegration test is also used by Mukherjee (2018), as the test allows for more than 1 cointegrating relationship.

The VAR and VECM models, as well as the Johansen cointegration tests were used to test for market efficiency (Mukherjee, 2018). The research specifically places emphasis on not taking the first difference for the VAR model. Especially if the spot and forward rates are of first order of integration and cointegrated. Then the VAR models at first difference would be misleading because the error correction terms are not specified. Mukherjee (2018) did not difference the variables for the VAR models but instead used the VECM from the VAR model instead.

Kumar & Kamaiah (2016) tested weak form market efficiency of BRICS countries for the period April 1994 to September 2014. The tests included variance ratio tests. Non-linearity was tested using the BDS test, Hinich bispectrum test and the Ter*ä*svirta neural network test (Kumar & Kamaiah, 2016). To test for chaotic behaviour, the estimate of the Largest Lyapunov exponents (LLEs) was done. The variance ratio tests rejected weak form efficiency for all 5 countries. All 5 countries' series data confirmed non-linearity of the data. The LLEs test confirmed chaotic structure for all 5 foreign exchange markets.

Weak form market efficiency of seven South Asian countries was tested by Noman & Ahmed (2008) from 1985 to 2005. Unit root and variance ratio tests were used to test the RWH. The foreign exchange rates of these seven countries were found to not be serially correlated and were found to be weak form efficient.

The Asia-Pacific currency markets were investigated for market efficiency (Ahmad, Rhee & Wong, 2012). Efficiency was tested during the Asian financial crisis from 1997 to 1998 and the global financial crisis from 2008 to 2009. The Johansen cointegration technique showed that countries displayed weak form efficiency. However, Fama's (1984) regression technique did not indicate market efficiency. The Pilbeam and Olmo (2012) model was used as the determining model to resolve the conflicting results. The Pilbeam and Olmo (2012) model revealed that the countries display in-country efficiency (Ahmad, Rhee & Wong, 2012). The model indicated that free floating currencies are more robust than those with a high degree of intervention.

8.2.3. Traditional Supply, Demand and Microstructure Based Tests

The study of securities microstructure deals with the investigation of individual participants in those markets alongside the influence of institutional rules on the economic performance of those markets (Flood, 1991). Microstructure analysis has highlighted participant behaviour and the effects of policies. It is applicable to the FX market because the market primarily matches buyers and sellers. Kitamura (2016) investigates forex market efficiency through the use of liquidity levels and information factors. The researcher suggests that stock markets consider the degree of efficiency of a market to be the inverse of the predictive power of order flow. This concept is applied to the forex market.

The research differs from conventional order flow market efficiency assessments by considering a positive increase in order flow as a signal for the appreciation of the base of a currency pair. The base currency, being the first currency quoted in a currency pair. Other studies use the linear predictive power of volume flow to predict future spot rates (Kitamura, 2016). For example, studies by Hradzil (2010) regress current price change onto lagged order flow imbalance to measure market efficiency. The study defines order flow imbalance as the difference between buy and sell orders over a specified period. Order imbalance flow was found to have low power in predicting future spot exchange rates (Kitamura, 2016). A statistical framework was applied alongside order flow to achieve a measurement of market efficiency. The Merton (1981) and Henrikkson and Merton (1981) market timing framework was applied.

The results show that order flow had little predictive power in predicting FX rates and FX markets displayed market efficiency.

Market efficiency measures were seen to decline during the bankruptcy of Lehman brothers and the Eurozone crisis, suggesting that turmoil in the financial crisis reduces market efficiency (Kitamura, 2016). Kitamura (2016) also suggests that increased liquidity increases market efficiency. As a highly liquid market implies more competition between traders and an improved rate of information transfer when compared to an illiquid market. Overall, Kitamura (2016) found that USD/JPY and EUR/USD FX markets are efficient, and their efficiencies are affected by market turmoil and liquidity to some extent.

The role of trading in exchange rate price formation is examined through order flow (Love & Payne, 2006). Order flow is defined as the net difference between buy and sell initiated transactions. Order flow contains information about long run risk premia. The USD/GBP, USD/EUR and GBP/EUR were investigated to test whether U.K and U.S macroeconomic public

announcements influenced exchange rate prices and the role of order flow. Textbook asset pricing theory suggests that macroeconomic fundamentals are a large component of exchange rate determination and then new macroeconomic announcements are incorporated into pricing within seconds. Love & Payne (2006) find that unexpected macroeconomic announcements have significant effects on exchange prices. This news also has a significant impact on order flow. The order flow changes are in the same direction as the exchange rate changes. Therefore, a component of the process of incorporating macroeconomic announcements into prices is attributable to trading. One third of the price adjustment is credited to order flow (Love & Payne, 2006). The findings do however not suggest that markets are inefficient, as the incorporation of announcements into prices occurs within two minutes.

Evans & Lyons (2002) propose that macroeconomic models used in exchange rate price determination do not account for the aggregation of information and that models using order flow do. The portfolio shift model used explains 60 percent of the Deutsche Mark/Dollar rate at a daily frequency and 40 percent of the daily changes in Yen/Dollar exchange rate. The model developed suggests order flow is influenced by interest rate changes and expected changes in future interest rates. Hence, influencing changes in exchange rates.

A monetary model of exchange rates which assumes sticky domestic goods prices described an overshooting the equilibrium exchange rate level due to a permanent shock in money supply. After an increase in money supply, the exchange rate depreciates more than what is required in the long-run and then appreciates to its long run value. During adjustment, the exchange rate changes are found to be serially correlated (Levich, 1989). It is argued that efficiency could present as exchange rates deviate randomly from equilibrium and with a mean zero from the equilibrium value, with the process wandering in a serially correlated fashion (Levich, 1989).

8.2.4. Random Walk Tests

8.2.4.1. Developing Market Random Walk Behaviour

Lo and MacKinlay's (1988) variance ratio test has been applied for testing the random walk hypothesis in the context of the Pakistan foreign exchange market (Rashid, 2006). The 5 exchange rate pairs investigated were the Pakistani Rupee/ US Dollar, Pakistani Rupee/British Pound, Pakistani Rupee/ Japanese Yen, Pakistani Rupee/ Deutsche Mark and the Pakistani Rupee/ French Franc. The researcher proposed that unit root testing alone is not a comprehensive test of market efficiency, as there is some departure from the random walk that unit root testing cannot detect (Rashid, 2006). The research investigates nominal time series data for 5 currency pairs over a period of 10 years. The study concludes that the currency pairs follow random walks. The research found that the exchange rate today is the best predictor of future spot exchange rate and not historical prices.

Almudhaf (2014) investigated the random walk hypothesis (RWH) for Colombia, Indonesia, Vietnam, Egypt, Turkey and South Africa (CIVETS) foreign exchange rates versus the U.S. Dollar. Weekly frequency time series data was used from 2007 to 2012 was used. Variance ratio tests were used. The Vietnamese Dong and Egyptian Pound violated the RWH. The Turkish Lira, South African Rand and Indonesian Rupiah were found to be weak form efficient for the time period considered (Almudhaf, 2014).

The RWH was investigated for the Zambian foreign exchange market (Mbululu, Auret & Chiliba, 2013). Lo and Mackinlay's (1988) variance ratio test and Wright's (2000) non-parametric ranks and signs based variance ratio test was used. Daily U.S Dollar/ Zambian Kwacha time series data was used for the research. The time period spans 2003 to 2012. Each of the variance ratio tests reject the RWH for the time period considered. This suggests that arbitrage opportunities were

available during the time period and above average returns could be realised upon correct speculation.

Random walk behaviour was investigated for the Euro/Serbian Dinar exchange rate (Gradojević, Djaković & Andjelić, 2010). Lo and Mackinlay's (1988) and Wright's (2000) variance ratio tests were used. The time series data investigated was of a daily frequency investigated from January 2005 to December 2008. The RWH was rejected for the time period considered and the exchange rate found to be inefficient.

8.2.4.2. Developed Market Random Walk Behavior

Charles & Darné (2009) conducted research on the random walk behavior of currency pairs relative to the Euro. Currencies included the Australian Dollar, British Pound, Japanese Yen, Canadian Dollar, Korean Won, Singapore Dollar, Norwegian Kroner, Swiss Franc and Swedish Kroner relative to the U.S. Dollar. The frequency of the data was daily and weekly frequency data. The time period was 4 January 1999 to 30 May 2008. Multiple variance ratio tests were used. These tests are robust and overcome non-normality and heteroskedasticity. These tests are the Chen and Deo (2006) power transformed tests and the multiple Belaire-Franch and Contreras (2004) rank and sign based tests.

When considering the daily data, the RWH is rejected for Singapore at the 5% level (Charles & Darné, 2009). It is suggested that the reason for rejection is the highly regulated nature of the Singapore's FX market. The RWH is rejected for Australia, Sweden and Norway for short time horizons. Implying that investors do not take short-term risky speculative decisions (Charles & Darné, 2009). Considering the other currencies, the RWH is not rejected at all lags.

Euro-based exchange rates for Australia, Canada, Japan, U.K, New Zealand, Korea and Switzerland follow the RWH for weekly and daily time series data sets, were found to be weak form efficient series. For Singapore and Norway, the RWH is rejected at a daily frequency but not at a weekly frequency. Suggesting arbitrage opportunities from speculation over the short-term horizon (Charles & Darné, 2009).

Blake, Beenstock & Brasse (1986) investigated the performance of U.K. forecasters attempting to forecast U.K. exchange rates based on econometric and economic analysis. The forecasts were found to be inefficient over a 12 month period. Indicating market efficiency.

The RWH was tested on the EUR/USD by Chen (2008). The time period under study was from 1999 to 2008. Three variance ratio tests were used, the Lo-Mackinlay's (1988), Chow-Denning's (1993) and Wright's (2000) non-parametric ranks and signs based variance ratio test. All three tests indicated that the EUR/USD exchange rate is weak form efficient (Chen, 2008).

8.2.5. Weak Form Efficiency Tests

8.2.5.1. Developed Market Weak Form Efficiency Testing

Research has been conducted into weak form efficiency of the EUR/CHF bilateral exchange rate from the period 2002 to 2017 (Yang, Shao, Shao & Stanley, 2019). The Hurst index was used to indicate the classification of market efficiency. High frequency intraday frequency tests of the EUR/CHF revealed a downward departure from 0.5 which was interpreted as evidence of intraday market inefficiency. When investigating long period returns, Hurst indices approached 0.5, indicating market efficiency. Intraday EUR/CHF returns showed a large departure from 0.5. The intraday Hurst indices present a lower bound which can be interpreted as a turning point of market

efficiency, suggesting that intervention by the Swiss National Bank during the period undermines market efficiency.

Makovský (2014) studied forex exchange rates of the Czech Koruna against the Euro. Monthly data for the period February 2001 to January 2013 was used. Each monthly data point represented the average of 30 days spot rates. Pedroni (Engle-Granger based) cointegration tests (Makovský, 2014). The test rejected co-integration or a long-term relationship between exchange rates and interest rates in the panel data set. Simple, Linear co-integration also showed rejection of a long run relationship. This implies weak form market efficiency as future spot rates cannot be predicted by new macro-economic information such as interest rate differentials. Interest rates cannot be used as a predictor as it has already been priced into the market. Evidence is seen by no cointegrating long run relationship between interest rates and exchange rates. Makovsky´ (2014) also suggests that in the short run trader psychology plays a role in spot rate volatility, and that investors are not homogenous in their opinions.

8.2.5.2. Developing market weak form market efficiency testing

Weak form efficiency was investigated in Namibia using the Augmented Dickey- Fuller (ADF), Phillips Perron (PP) and Kiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests (Engelbrecht, Mabakeng, Peyavali & Sheefeni, 2014). The KPSS was added by the research team because the ADF and PP tests were found to under-reject the RWH.

Reasons for conducting the research in the Namibian FX market was that inefficiency in Namibia's foreign exchange market would result in investment analysis creating abnormal returns, create increased and abnormal volatility, increasing exchange rate uncertainty which would filter into Namibian trade and investment. Considering that Namibia has a highly concentrated export market

is highly dependent on exports, exchange rate fluctuations are a key concern for its economy. The same could be argued for South Africa, as it is a net exporter of goods when considering its trade balance. Therefore, the strengthening or depreciation of the exchange rate affects the competitiveness of both Southern African countries' exports. Strengthening the argument for investigation into the efficiency of the South African FX market efficiency.

Inefficiency in the FX market may force governments to intervene to reduce exchange rate volatility and evaluate policies which can be used to curb it (Engelbrecht, Mabakeng, Peyavali & Sheefeni, 2014). The study used monthly data from January 1993 to December 2011, using unit root testing. The results confirm market efficiency in Namibia's FX market. Therefore, historical exchange rate data cannot be used to predict future exchange rates. The study also showed that the Namibian stock market is weak form efficient owing to its correlation with the Johannesburg Stock Exchange, which is also weak form efficient.

Weak form efficiency was investigated for the exchange rates of 30 countries forming part of the Organisation for Economic Cooperation and Development (OECD) (Ibrahim, Long, Ghani & Salleh, 2011). Augmented Dickey-Fuller (ADF), Philip-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests were conducted to investigate whether future price movements could be speculated based on historic time series data. Weekly data for the period 2000 to 2007 was tested. Exchange rates for all 30 countries tested were found to be weak form efficient.

Multi-scale approximate entropy (MApEn) was used to classify the degree of weak form market efficiency of foreign exchange markets for 17 countries (Wang & Xie, 2011). The countries included developed and developing countries. Testing was done during the South East Asian currency crisis and the global financial crisis to investigate the effect on exchange rate market efficiency. MApEn was used to classify the randomness of FX markets. Daily exchange rate data

from 1984 to 2011 was used. Developed FX markets were found to be more efficient than developing FX markets. The global financial crisis was also found to improve the efficiency of developing FX market efficiency (Wang &Xie, 2011).

8.2.6. Semi-Strong Form Efficiency Tests

8.2.6.1. Developing Market Efficiency

Market efficiency of the Botswana FX Market was tested from January 2000 to December 2015 (Matebejana, Motlaleng & Juana, 2017). The Botswanan Pula against the South African Rand, Japanese Yen, British Pound and U.S Dollar were tested. Weak form efficiency was tested using unit root testing. The tests employed include the ADF, KPSS and PP unit root tests to test for a random walk generating process.

The KPSS, ADF and PP indicated that the Botswana FX market is weak form efficient. The Pula versus the South African Rand, Yen and U.S Dollar were found to be non-stationary. This implies random walk behavior and weak form market efficiency according to the RWH. Therefore, individuals are unable to generate abnormal returns using historical exchange rate information.

However, unit root tests concluded that the Pula versus the Pound was stationary at first difference and at levels (Matebejana, Motlaleng & Juana, 2017). Thus, the Pound was found to be inconsistent with the RWH hypothesis and is not weak form efficient. Research found significant patterns when plotting the time series data graphically. This suggests that speculators can predict the future direction of the Pula/British Pound, by establishing a trading rule devised from historical time series plots.

The semi-strong form of market efficiency of the Botswana FX market was tested. The method of testing took the form of cointegration tests. Cointegration tests were only conducted on non-stationary exchange rate crosses. Being the Pula against the Rand, Yen and U.S. Dollar. Results indicated one cointegrating relationship or equation when considering the three crosses, in the trace test as well as maximum eigenvalues at a 0.05% level of significance.

The presence of a cointegrating relationship indicates no random walk and rejection of the semi-strong form market efficient hypothesis. Therefore, the results imply that a trader could possibly predict future exchange rates based on a pattern trading rule. The test conducted does not specify which currency pair displays a cointegrating relationship, only that one exists among the three. It was assumed that because the Pound was weak form inefficient, it was also semi-strong form inefficient. This is in line with efficient market hypothesis theory which states that if a series is not weak form efficient it cannot be semi-strong form efficient. The lowest level of efficiency must first be attained.

The testing done shows that the Botswana FX Market is not semi-strong form efficient (Matebejana, Motlaleng & Juana, 2017). Botswana's exchange rate policy has helped maintain weak form efficiency.

Weak and semi-strong form market efficiency was investigated in Sri Lanka's FX market from the period January 1986 to November 2000 (Wickremasinghe, 2004). The nominal exchange rate data followed a monthly frequency. Weak form market efficiency was tested using unit root tests. Semi-strong market efficiency was tested using cointegration tests, Granger causality tests and variance decomposition tests. The exchange rates investigated include the Japanese Yen, U.K Pound, U.S. Dollar, French Franc, German Mark and Indian Rupee. The unit root tests revealed all six exchange rates to be weak form efficient and display random walk generating processes.

The cointegration, Granger-causality and variance decomposition tests reveal that the nominal exchange rates are not semi-strong efficient. The tests indicate that the movement of one exchange rate can be predicted through another exchange rate's movement. This implies that market participants are able to engage in arbitrage opportunities in the long and short run (Wickremasinghe, 2004).

8.2.6.2. Developed Market Efficiency

The USD/EUR was tested for efficiency by using the conventional uncovered interest parity regression approach and orthogonality test of the forward rate forecast error (Czech & Waszkowski, 2012). The period under investigation was from 1999 to 2007 and from 2010 to 2007. Both prior to and after the financial crisis and quantitative easing periods. It was found that uncovered interest parity conditions hold better in times of crisis. The semi-strong form market efficiency hypothesis was rejected due to the outcome of the orthogonality test of the forward rate forecast error. The null hypothesis that the forward forecast error was orthogonal to its lagged value and interest rate differential was rejected. The reason given for rejection of market efficiency was perhaps that economic agents are irrational and are prone to risk taking.

Research has been conducted to investigate the efficacy of using network neural regression (NNR) techniques to forecast and trade the EUR/USD (Dunis & Williams, 2002). The NNR approach was benchmarked against to traditional forecasting techniques to investigate potential performance. NNR models were created using in sample data from 1994 to 1999. Out of sample forecasting was conducted from 2000 to 2001. Correct forecasting would imply market inefficiencies. Cumulatively, forecasts using NNR methods were correct 57% of the time. Although more than 50% of trading opportunities were judged correctly, this is similar to the probability of flipping a

coin and landing either heads or tails. The research shows no outright evidence for sole reliance on NNR models alone to correctly forecast EUR/USD movements. This highlights the efficiency of the market.

Levich (1978) conducted empirical research which finds that foreign exchange markets are volatile which does provide large profit opportunities. However, this does not mean that these markets are inefficient. Levich (1978) did not find conclusive evidence that foreign exchange markets are inefficient. In the short run, the exchange rates do not reflect all information. Traders pay for information and take positions based on it and over the long run, exchange rates shift to their correct levels.

Modified Hurst exponent and volatility modelling was used on time series exchange rate data log returns (Yaya, Saka & Akanbi, 2019). The results showed that the future path of exchange rates was not a result of previous price values. The study was conducted for the US Dollar- South African Rand and Us Dollar- British Pound exchange rates. Both sets were found to be weak form efficient since 2001.

8.2.7. Strong Form Efficiency Tests

Mahajan & Mehta (1984) Investigated strong form efficiency in the British Pound versus the U.S. Dollar exchange rate market. The research investigated commercial banks' ability to formulate superior market expectations. Stein's theory was used to distinguish between shifts in market equilibrium and the swap transactions framework was used to investigate the differences between bank expectations and actual observed market behaviour. The swap positions of banks were examined to gauge banks' expectations based on their forward positions. The outcome of the research was such that banks had better than random forecasting ability (Mahajan & Mehta, 1984).

It was found that banks' ability to correctly judge exchange rate market direction was process driven and not random. They were able to profit from their foreign exchange rate operations. This does not necessarily imply inefficiency in the international foreign exchange market. As risk premium compensation requires non-random expectations (Mahajan & Mehta, 1984).

Empirical studies show that the forex market is volatile and that considerable profit opportunities do exist. However, this is not evidence to suggest that markets are inefficient, statistical evidence is unable to reject efficiency in the event that it should. Partly because, an alternate hypothesis has not yet been defined (Levich, 1978). It has been suggested that market efficiency is a process, rather than a hypothesis. Furthermore, it has been found that in the short run the foreign exchange market does not fully reflect all information. As time passes, traders analyze information, take positions, money supply shifts and the exchange rate market moves towards a position of reflecting all information (Levich, 1978).

8.2.8. Behavioural Finance Studies

Behavioural finance models in determining exchange rate prices are founded on the premises that economic agents are limited in their capacity to understand the complexities of the world around them. Agents therefore rely on simplistic rules to forecast exchange rate movements. Making use of behavioural rules which account for only a small piece of the total information set (De Grauwe & Kaltwasser, 2006). The model developed is based on the assumptions that agents can use multiple forecasting rules and that they cannot fully comprehend the full impact and consequence of economic policy decisions. The results from modelling the exchange rate market showed that the rate switches from one equilibrium to another as a result of stochastic disturbances. Creating

cyclical movements around the fundamental rate. The result is not influenced by the forecasting rules chosen by economic agents.

It was also found that the exchange rate is sensitive to initial conditional disturbances. Whereby, an initial, small disturbance can alter its future time path drastically. Creating new disturbances which were a function of the initial.

The study also found that when economic agents changed their opinion about the opinion of the underlying fundamental exchange rate, the direction of the exchange rate changed significantly.

The model also displays volatility. It was found that volatility is a function of the number of rules economic agents can choose from and the uncertainty they have regarding the underlying fundamental value of the exchange rate.

The behavioural model departed from traditional efficiency approaches in modeling the exchange rate because of the poor empirical results that traditional expectations models produced in the past (De Grauwe & Kaltwasser, 2006).

Behavioural equilibrium exchange rate methodology was used to determine the real effective equilibrium exchange rate of the South African Rand. For the purpose of determining whether current rates are aligned with the equilibrium rate (Khomo & Aziakpono, 2016). Misalignment is explored using the Markov regime switching model. The results of the research show a cointegrating relationship between the exchange rate, terms of trade, external openness, capital flows and government expenditure. The research also suggests that the exchange rate is not aligned with the equilibrium level.

Four overvaluation episodes were identified in the periods: 1986-1988, 1997-1998, 2003-2006, and 2010-2012. Undervaluation was captured for the majority of the period studied (1985-2014).

Extreme undervaluation of the Rand was seen during the period of the 2007/2008 financial crisis (Khomo & Aziakpono, 2016). The Rand was also seen to be undervalued in the period 2013-2014. The exchange rate was found to be more undervalued than overvalued, with undervalued periods lasting longer than overvalued periods.

An undervalued currency is seen to benefit from growth through increased exports (Khomo & Aziakpono, 2016).

Highlighting the importance of the efficiency of the Rand exchange rate. Exchange rate inefficiencies which reduce the competitiveness of South African exports may be restricting economic growth.

8.2.9. The Impact of Monetary Policy on Exchange Rates

Monetary policy displays a strong impact on exchange rates. Unconventional monetary policy such as that of ultra-low interest rates was found to affect exchange rate in much the same way as conventional policy. The sensitivity of the exchange rate to monetary policy has increased over time (Ferrari, Kearns & Schrimpf, 2017). The FX impact of monetary policy was found to be state dependent and was found to be stronger the lower the level of interest rates. Exchange rates were found to adjust more significantly at lower levels of interest rates. Macro-economic data releases were found to have minimal impact in a change from historic versus current exchange rate adjustments.

9. Summary and Gap Analysis

The FX Market is the largest financial market in terms of daily volume traded per day. It acts as a link to gain purchasing power and invest in commodities, financial securities, hedging instruments

and facilitates trade between countries in a globalized financial market. Market efficiency has significant consequences for governments and policy makers. An inefficient market may require intervention by governments to encourage the market to return to an acceptable level of equilibrium. An inefficient FX market implies that market participants can make abnormal profits based on a trading rule. This may result in abnormal volatility in the market and affect the competitiveness of a country's exports. In the case of South Africa, which is a net importer of goods, the competitiveness of exports may significantly be affected by currency fluctuations. The quantitative easing period in the U.S. resulted in cash flooding the financial markets. This excess liquidity may or may not have affected market efficiencies. Which can be investigated for the ZAR/USD currency cross pair.

Much research in investigating FX market efficiency has focused on European and U.S. base currencies. Research of the South African Rand relative to the U.S. Dollar has not been exhausted and there appears to be scope for research for the period during the 2008 financial crisis. Research can also be extended from only relying on unit root testing to investigate weak form efficiency, but also to consider stronger form efficiency in the case of UIP and cointegration tests, if a number of currency pairs relative to a U.S. Dollar base are investigated. Such testing could also be extended to include Euro base versus BRICS currency pairs to further investigate the effect of quantitative easing on forex market efficiency.

Research suggests that increased liquidity makes markets more efficient as opposed to less efficient. However, this should be confirmed through testing using the econometric techniques outlined in this literature review.

Investment banks have been found guilty of rigging the South African Rand through coordinated trading activities to push the ZAR/USD to a desired level for the purpose of generating a profit. In

the short run, these banks create inefficiencies in the market and are themselves the source of market inefficiency. Given that the interbank bank market constitutes more than 80% of volume in the FX market, the monopoly that large investment banks share presents the option to take advantage of the large volume of trades they place. Market intervention by these banks distorts the natural equilibrium of the FX markets. Quantitative easing also distorted the conventional equilibrium of the FX market. Considering that the U.S. Dollar featured 88% of the time on one side of a currency cross pair as at April 2016 (BIS, 2016) when considering total turnover in the FX market worldwide. The U.S. Dollar plays a significant role in the global financial market and it is also the currency in which commodities such as gold and oil are quoted in for the purpose of trade.

The high volume and liquidity of the Dollar throughout the FX market by turnover would imply a high degree of market efficiency; however, inefficiencies such as rigging of the Rand and intervention by the U.S. Federal Reserve may have brought about market inefficiencies during the 2008 financial crises and the years following. The excess liquidity may have given rise to the presence of arbitrage opportunities.

10. Methodology

Market efficiency tests were conducted in intervals relative to the European (2015-2018) and U.S. (2008-2017) quantitative easing periods. Market efficiency was tested 2 years prior to the QE period concerned, during it and 2 years after it. This was done for BRICS currency pairs relative to the U.S. and BRICS currency pairs relative to the Euro.

Currency pair data was sourced from a Bloomberg terminal. The data was of a monthly frequency. The currency 3 month forward rates and monthly interest rates per country were also sourced from a Bloomberg terminal.

The data was first analysed using descriptive statistics. The data was then investigated for stationarity through unit root testing. If the data was found to have unit roots and be non-stationary, the data was differenced. The data was then tested for autocorrelation. The data should not be dependent on a previous data point or related to a previous data point if the time series is fully efficient. Autocorrelation and unit root tests were used as initial indicators of price inefficiency.

The study then undertook more formal tests of price efficiency. Variance ratio testing was done to test the characteristics of the variance of the differences between data points in the time series. The profile of these variances was contrasted against that of a random walk variable to determine price efficiency. Semi-strong forms of market efficiency were tested by investigating whether the forward exchange rate is an unbiased predictor of the spot exchange rates and whether a cointegrating relationship exists among a set of exchange rates. UIP testing was also conducted and considered a more formal test of market efficiency.

10.1. Testing for Stationarity and Autocorrelation

10.1.1. Unit Root Tests

Unit root tests test for stationarity and non-stationarity or the presence of a unit root. The unit root tests considered include the Augmented Dickey Fuller (ADF), Philips Peron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. The power and type I error was considered for all three tests when testing for a null hypothesis of stationarity against an alternative hypothsis of a unit root, at sample sizes of 20, 40 increasing increments to 200. The power of these tests was

considered for first, second and third order moving average, autoregressive and mixed autoregressive moving average models (Imam, Habida & Atanda, 2016). It was found that PP unit root tests performed the best when considering the sample sizes and model types (Imam, Habiba & Atanda, 2016). Therefore, PP unit root testing was undertaken.

10.1.2. Augmented Dickey Fuller Test

The Augmented Dickey Fuller Test tests for the presence of a unit root. The null hypothesis of the ADF test is the presence of a unit root. It is of the form:

$\Delta x_t = a_0 + b_0 x_{t-1} + \Sigma c_0 \Delta x_{t-1} + \varepsilon_t$

Where: a_0, b_0, c_0 Are coefficients to be estimated. Unit roots are investigated for the series, Δx_t.

ε_t is the error term at time t. If a unit root is found, the series is non-stationary.

10.1.3. Philips Peron Test

The Philips Peron (PP) Test investigates whether a time series data set is of order of integration 1 or I (1). This implies that the series is stationary at first difference. If the series is not stationary it is said to contain a unit root and be a random walk process. The null hypothesis of the PP test is the presence of a unit root. The Philips Peron Test is indicated as follows:

$\gamma_i = \alpha + p y_{t-1} + \varepsilon_t$ Where: α, p Are parameters to be estimated.

The Augmented Dickey Fuller (ADF) Test and Philips Peron Test indicate whether exchange rate time series data are weak form efficient (Amelot, Ushad & Lamport, 2017). The Augmented-Dickey Fuller (ADF) and Philips Peron (PP) unit root tests were used to test weak form efficiency

in Mauritian cross currency pairs (Amelot, Ushad & Lamport, 2017). These tests revealed that the currency pairs were weak form efficient.

10.1.4. KPSS Testing

The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root test tests whether a given time series is stationary around a deterministic trend (Matebejana, Motlaleng & Juana, 2017). The null hypothesis is that of stationarity. The alternate hypothesis is that of a unit root process alternative. The unit root process alternative or difference stationary process is a stochastic trend in a time series. If a time series has a unit root it is unpredictable. The KPSS differs from the ADF and PP tests in that it tests for stationarity against a unit root alternative process which is unpredictable (Matebejana, Motlaleng & Juana, 2017).

The KPSS test considers the observed time series as the sum of a deterministic trend, a random walk and a stationary residual. The test can be described as: $Y_t = \beta t + (r_t + \alpha) + e_t$.

With $r_t = r_{t-1} + u_t$ as a random walk, with the initial value $r_0 = \alpha$ as the intercept. All u_t residuals are independent and identically distributed (Matebejana, Motlaleng & Juana, 2017).

The null hypothesis, H_0: Y_t is level stationary or a trend. The alternate hypothesis, H_1: Y_t is a random generating process or a unit root process.

If the test reveals that the time series is non-stationary at levels or first difference, the series is considered to be weak form efficient.

10.1.5. Autocorrelation: Box-Pierce and Ljung-Box Q-Statistics

Autocorrelation refers to the similarity between successive data points in time series data. A truly random series should not display autocorrelation. As the opposite would suggest that future data

points are dependent on historical ones. Rashid (2006) makes use of the Box-Pierce and Ljung-Box Q-Statistics (1970) to test market efficiency. The test has a null hypothesis of autocorrelation coefficients simultaneously equal to zero. The Q-statistic investigates departure from no autocorrelation in both directions for all time lags constrained by the number of degrees of freedom. The Q-statistic follows a Chi-Square (χ^2) distribution with *m* degrees of freedom. For small samples, Ljung and Box (1987) also provide a correction which allows for better fit of the Chi-Square distribution. Successive time series data points should be uncorrelated if a random walk hypothesis is to be anticipated.

10.2. Variance Ratio Testing

10.2.1. Variance Ratio Test

The variance ratio test calculates the variances for each difference in the data set. The variances are compared to one another such that a q period variance should be equal to q times the variance of the first period data difference. This restriction holds true for a random walk variable.

The variance ratio test exploits the fact that the variances of the differences of a random walk series increases linearly.

Researchers who have investigated the efficiency of currency markets have found that trend following has been worthless since 2000 (Pukthuanthong-Le & Thomas, 2008). Suggesting that currency markets were weak form inefficient prior to 2000 but have since become efficient. The reason being that the market was immature prior to 2000.

10.2.2. Multiple variance ratio test applied to 15 emerging capital markets

The multiple variance ratio test, developed by Chow and Denning (1993), as well as a runs test was used to investigate random walks and market efficiency in 15 emerging capital markets (Karemera, Ojah & Cole., 1999). The presence of random walks underpins efficient market hypothesis testing. The generating process which describes the time series for a data set of equity prices consists of permanent components if it follows a random walk process. This implies no mean reversion. Thus, innovations or shocks to the series, in the form of news events should cause a deviation from its long-term equilibrium. The random walk nature of equity returns is perceived to be a result of market efficiency (Karemera, Ojah & Cole, 1999).

If a time series contains a unit root, it implies the series shows the series is unpredictable (Ojah & Karemera, 1999). Unit root tests lack strength in rejecting the RWH for a stationary series when the RWH is false, resulting in problems associated with unit root testing (Summers, 1986). Unit root tests also have difficulty in detecting departures from a random walk. The Lo and Mackinlay (1988) variance ratio test seeks to address this by considering each individual variance ratio step. Each increment variation ratio deviation from unity is investigated (Karemera, Ojah & Cole, 1999). The correlation from one variation ratio to the next is studied. Variances are to be uncorrelated if a random walk persists. The Lo and Mackinlay (LOMAC) tests were created to overcome the problems associated with unit root testing. The LOMAC is a single variance ratio test of unity and requires that all variance ratios be of unity. This cannot be the case for all intervals at the same time when considering past time series data. The test is therefore susceptible to inefficiencies. A multiple variance ratio F-test which investigates all variance ratios at once was developed by Chow and Denning (1993) to overcome the problems of the LOMAC test. The Chow

and Denning (CHODE), test is as effective, if not more effective, than the Augmented Dickey Fuller (ADF) unit root tests (Karemera, Ojah & Cole, 1999).

A total of 10 of the 15 emerging equity markets studied by Karemera, Ojah & Cole (1999) were consistent with the RWH using the CHODE test procedure. The other 5 were consistent with the RWH under the LOMAC test procedure (Karemera, Ojah & Cole, 1999). It is my aim to use variance ratio testing within the forex market, to investigate weak form market efficiency both before the 2008 financial crisis, during, and after. Variance ratio testing will also be conducted before the European quantitative easing period, during it and after it.

10.3. Cointegration Testing

For a market to be considered efficient, the forward exchange rate is expected to be an unbiased predictor of future spot exchange rates (Hallwood & MacDonald, 2000). Therefore, a long run relationship between the forward exchange rate and spot exchange rate at time t+3, for example should exist. Cointegration testing can be used to test for this relationship. All currency pairs should be tested for cointegration. However, due to the large amount of state intervention by the Chinese government in their currency, the forward rate may not be an unbiased predictor of the future spot rate.

Cointegration of variables suggests that the variables have a long run relationship and move together at some point in the long run. They have a long run link. Generally, cointegration testing is done after the first order of integration. If the time series is integrated at levels, it is said to be cointegrated. The Johansen test of cointegration is seen as a robust test for investigating long run relationships between variables. It is seen as a robust technique for market efficiency testing in the FX market (Matebejana, Motlaleng & Juana, 2017).

The Johansen test uses two sets of statistics. The maximum eigen value statistics and trace statistics. This test allows the test of more than one cointegrating relationship, whereas the Engle-Granger method of testing tests only one relationship. The Johansen test is however subject to unreliability in the case of small sample sizes.

10.5. Uncovered Interest Parity (UIP) Testing

Mukherjee (2018) tested UIP for BRICS countries against the U.S. Dollar. This research seeks to follow the same approach in testing the UIP condition. UIP is expected to hold on the case of an efficient market (Hallwood & MacDonald, 2000). UIP is tested by investigating the relationship between the difference between the spot rate at t=0 and the forward rate at t+3, and whether this difference can be explained by the interest rate differential between the two countries concerned. The interest rate being the 3 month treasury bill per respective region in the period concerned.

The regression equation would be of the form (Mukherjee, 2018):

$$\ln(S_{t+3}) - \ln(S_t) = \alpha + \beta\left(i_{foreign} - i_{U.S.}\right) + \varepsilon_{t+1}$$

If the UIP condition holds, the respective forex market is found to be efficient. The UIP condition is found to hold if $\alpha = 0$ and $\beta = 1$.

10.6. Application of Testing Procedures

The data analysis was conducted by separating the data set into 3 segments such that analysis was conducted prior, during and post the quantitative easing periods. The U.S. data segments follow chronologically as; prior QE (January 2005- October 2008), during QE (November 2008- October 2017), post QE (November 2017 – August 2019). According to preliminary analysis, a significant price direction shift was seen after the first round of quantitative easing (QE1) and post the last

(QE3). The European quantitative easing periods follow as; prior QE (January 2005- February 2015), during QE (March 2015 – December 2018) and post QE (January 2019- August 2019). Data analysis as stipulated in the methodology was carried out for both U.S and European BRICS currency cross pairs.

Chapter 11 Data Analysis

11.1. Descriptive Statistics

The descriptive statistics per currency pair were investigated to quantify the characteristics of the data to be tested. Given that the exchange rate data appears to be trending and the volatility of cross pairs is not constant, the full set of descriptive statistics are not included in the body of this report. However, descriptive statistics to investigate whether the currency cross pairs follow a log normal process are included in Table 1 and Table 2.

	ZAR/USD			BRL/USD			RUB/USD			INR/USD			CNY/USD		
	Prior QE	**QE**	**Post QE**	**Prior QE**	**QE**	**Post QE**	**Prior QE**	**QE**	**Post QE**	**Prior QE**	**QE**	**Post QE**	**Prior QE**	**QE**	**Post QE**
Jarque-Bera	6.41060	7.85361	2.17059	1.43230	8.41908	2.27899	2.88713	15.51081	2.27782	1.01199	10.87836	0.85592	4.94614	10.10584	1.22108
Probability	0.04055	0.01971	0.33780	0.48863	0.01485	0.31998	0.23609	0.00043	0.32017	0.60291	0.00434	0.65184	0.08433	0.00639	0.54306

Table 1- Descriptive Statistics: Jarque-Bera Statistics and Probability Values for USD Cross Pairs

	ZAR/EUR			BRL/EUR			RUB/EUR			INR/EUR			CNY/EUR		
	Prior QE	**QE**	**Post QE**	**Prior QE**	**QE**	**Post QE**	**Prior QE**	**QE**	**Post QE**	**Prior QE**	**QE**	**Post QE**	**Prior QE**	**QE**	**Post QE**
Jarque-Bera	2.61387	1.10789	1.01188	2.83613	2.48416	0.16660	170.76170	1.59527	0.32264	5.49325	1.31215	0.82760	5.67265	2.80883	0.50459
Probability	0.27065	0.57468	0.60294	0.24218	0.28878	0.92007	0.00000	0.45039	0.85102	0.06414	0.51889	0.66113	0.05864	0.24551	0.77702

Table 2 - Descriptive Statistics: Jarque-Bera Statistics and Probability Values for EUR Cross Pairs

The natural log of the cross-pairs was taken, and normality investigated. Normality of a data set can be tested using the Jarque-Bera statistic and the corresponding probability value (Table 1 and Table 2). The null hypothesis for the test is that of a normal distribution. However, if the probability

value is less than 0.10 the null hypothesis of a normal distribution is rejected in favour of the alternate hypothesis of a non-normally distributed data set.

The ZAR/USD, BRL/USD, RUB/USD, INR/USD and CNY/USD did not follow a log-normal distribution during QE. The ZAR/USD and CNY/USD pairs did not follow a log-normal distribution prior QE but did follow a log-normal distribution post QE. The BRL/USD, RUB/USD and INR/USD were found to be log-normally distributed prior to and post QE.

All Euro currency cross pairs followed a log-normal distribution during and post QE. The RUB/EUR, INR/EUR and CNY/EUR did not follow a log-normal distribution prior to QE but did do so during and post QE.

When considering the period prior to US quantitative easing (2005.01-2008.10), U.S. cross currency pairs data, bar the ZAR/USD are platykurtic and follow a flat curved shape. The ZAR/USD data for the period is leptokurtic and peaked as shown by the kurtosis value of 5.86, which is greater than 3.

For the (2008.11-2017.10) U.S. quantitative easing period all U.S. cross currency pairs displayed a platykurtic distribution and the mean value of 4 currency pairs increased due to the strength of the U.S Dollar during this period. The CNY/USD pair strengthened during the period when considering mean values.

The (2017.11-2019.08) period post U.S QE showed an increase in the mean value of all currency pairs relative to the U.S QE period. All currency pair data displayed a platykurtic shape post QE.

When considering the period prior to the EU quantitative easing (2005.01-2015.02), all EUR currency cross pairs are platykurtic, during the EU QE period (2015.03-2018.12), almost all currency pair mean values increased when compared to the pre-QE period. The only pair not to

increase was the CNY/EUR. The shape for all Euro cross pair data can be described as flat curved. A platykurtic shaped suitably describes the (2019.01-2019.08) cross-pair data for the period post E.U. quantitative easing.

Empirical evidence suggests financial time series data tends to follow a non-normal distribution. Tests have been developed for non-normal time series data which may lead to non-normal GARCH type cointegration error distributions. These include the Dicky Fuller unit root tests, cointegration Dubrin-Watson test, the Wild Bootstrap test and the Johansen likelihood ratio tests (Kosapattarapim, Lin & McCrae, 2013).

11.2. Unit Root Testing

The purpose of the unit root testing is to investigate weak form efficiency. A weak form efficient process would be classified as non-stationary and a random walk.

According to research conducted by Imam, Habida & Atanda, 2016, it was found that PP unit root tests performed the best when considering sample sizes of 20, 200 and 400 and various model types (Imam, Habiba & Atanda, 2016). Therefore, PP unit root testing was undertaken, alongside the ADF and KPSS tests for confirmation of results. The unit root tests were undertaken as preliminary tests of market efficiency.

The null hypothesis of the PP and ADF unit root tests is that of non-stationary processes containing a unit root. The KPSS unit root tests state the null hypothesis as a stationary process having no unit root. A random walk process would imply weak form efficiency. The unit root tests were conducted at levels and at first difference. The results can be seen in Tables 3 and 4.

		Levels		First Difference		Levels		First Difference		Levels		First Difference	
	Period	ADF Test Stat	P-Value	ADF Test Stat	P-Value	PP Test Stat	P-Value	PP Test Stat	P-Value	KPSS Test Stat	5% CV	KPSS Test Stat	5% CV
	Prior QE	0.11989	0.96390	-4.89342	0.00020	0.09192	0.96160	-4.84848	0.00030	0.76019	0.463	0.200814	0.463
ZAR/USD	QE	-0.24841	0.92760	-11.02390	0.00000	-0.19645	0.93450	-11.00163	0.00000	0.98391	0.463	0.33212	0.463
	Post QE	-0.73497	0.81560	-6.64699	0.00000	-1.27860	0.61940	-6.54914	0.00000	0.48576	0.463	0.141243	0.463
	Prior QE	-1.95342	0.30580	-5.78745	0.00000	-1.95410	0.30550	-5.83161	0.00000	0.78962	0.463	0.290615	0.463
BRL/USD	QE	-0.46671	0.89230	-10.61854	0.00000	-0.62792	0.85870	-10.69259	0.00000	0.90453	0.463	0.200341	0.463
	Post QE	-1.40172	0.56170	-4.45809	0.00250	-0.95625	0.74900	-4.48253	0.00240	0.48132	0.463	0.271118	0.463
	Prior QE	-1.35439	0.59570	-2.69072	0.08370	-1.31415	0.61500	-2.65820	0.08950	0.73903	0.463	0.232382	0.463
RUB/USD	QE	-1.13161	0.70120	-7.38325	0.00000	-0.88608	0.78930	-6.98702	0.00000	0.90976	0.463	0.101687	0.463
	Post QE	-1.51636	0.50590	-5.16634	0.00050	-1.33160	0.59500	-5.32638	0.00040	0.44897	0.463	0.123564	0.463
	Prior QE	-0.95447	0.76110	-3.37445	0.01730	-0.81416	0.80540	-3.26184	0.02290	0.26427	0.463	0.328114	0.463
INR/USD	QE	-0.75654	0.82680	-10.47861	0.00000	-0.63163	0.85790	-10.71296	0.00000	1.06762	0.463	0.149123	0.463
	Post QE	-1.51215	0.50800	-4.21322	0.00420	-1.41105	0.55720	-4.18464	0.00450	0.42894	0.463	0.12933	0.463
	Prior QE	0.84336	0.99370	-4.81060	0.00030	1.23173	0.99790	-4.80580	0.00030	0.82570	0.463	0.359747	0.463
CNY/USD	QE	-1.39889	0.58030	-8.19771	0.00000	-1.36330	0.59760	-8.17611	0.00000	0.33677	0.463	0.41067	0.463
	Post QE	-0.34062	0.90280	-2.62704	0.10430	-0.60046	0.85060	-2.53146	0.12340	0.45019	0.463	0.164545	0.463

Table 3. Unit root test output data per USD currency pair. The time periods are as follows: "Prior QE" (January 2005-October 2008), "QE" (November 2008-October 2017), "Post QE" (November 2017-August 2019). The time series data is of a monthly frequency.

		Levels		First Difference		Levels		First Difference		Levels		First Difference	
	Period	ADF Test Stat	P-Value	ADF Test Stat	P-Value	PP Test Stat	P-Value	PP Test Stat	P-Value	KPSS Test Stat	5% CV	KPSS Test Stat	5% CV
	Prior QE	-1.38485	0.58770	-11.05357	0.00000	-1.40053	0.58020	-11.05342	0.00000	0.77865	0.463	0.082946	0.463
ZAR/EUR	QE	-2.60994	0.09850	-7.91417	0.00000	-2.57595	0.10540	-7.86931	0.00000	0.13068	0.463	0.101122	0.463
	Post QE	-3.16763	0.06667	-2.38618	0.17850	-4.87315	0.00930	-3.02276	0.08640	0.39745	0.463	0.280619	0.463
	Prior QE	-2.42309	0.13760	-11.76161	0.00000	-2.37728	0.15030	-11.74743	0.00000	0.23781	0.463	0.335025	0.463
BRL/EUR	QE	-1.46493	0.54200	-6.59061	0.00000	-1.50443	0.52230	-6.59070	0.00000	0.26756	0.463	0.109478	0.463
	Post QE	-2.38844	0.17450	-2.52601	0.15280	-2.49575	0.15340	-2.48469	0.15990	0.35361	0.463	0.211662	0.463
	Prior QE	-1.19939	0.99800	-5.51166	0.00000	1.35605	0.99880	-3.91039	0.00270	0.99762	0.463	0.312090	0.463
RUB/EUR	QE	-1.64754	0.45060	-5.32586	0.00010	-1.73867	0.40540	-5.29292	0.00010	0.15467	0.463	0.105000	0.463
	Post QE	-1.65776	0.40820	-3.81102	0.04490	-1.74793	0.37120	-1.50060	0.46620	0.36743	0.463	0.500000	0.463
	Prior QE	-1.34556	0.60660	-10.49963	0.00000	-1.45034	0.55540	-10.54625	0.00000	1.02309	0.463	0.079224	0.463
INR/EUR	QE	-1.85812	0.34850	-7.15901	0.00000	-1.85834	0.34840	-7.72220	0.00000	0.05847	0.463	0.142635	0.463
	Post QE	-5.17201	0.00950	-2.64835	0.13330	-3.12159	0.07060	-2.64835	0.13330	0.42504	0.463	0.229424	0.463
	Prior QE	-1.05737	0.73080	-11.03711	0.00000	-1.05025	0.73350	-11.03795	0.00000	1.75322	0.463	0.051248	0.463
CNY/EUR	QE	-2.03172	0.27270	-8.33984	0.00000	-1.99524	0.28780	-9.78943	0.00000	0.81937	0.463	0.310634	0.463
	Post QE	-1.10153	0.64790	-2.37890	0.18000	-1.10153	0.64790	-2.60439	0.13990	0.32161	0.463	0.500000	0.463

Table 4. Unit Root test output data per EUR currency pair. The time periods are as follows: "Prior QE" (January2005- February 2015), "QE" (March 2015-December 2018), "Post QE" (January 2019 -August 2019). The time series data is of a monthly frequency.

The PP test at levels failed to reject the null hypothesis of non-stationarity at the 5% level of significance, when considering all 10 currency pairs, pre, during and post QE periods, for both the U.S. and E.U. cases (Table 3 & Table 4). The ADF test also showed a non-stationary generating process at levels for all 10 currency pairs at levels across all time periods, excluding the INR/EUR, at the 5% significance level. The INR/EUR ADF test at levels indicated a stationary, non-random walk process post E.U. QE, while a non-stationary process prior to and during E.U. QE.

The KPSS test at levels indicated a non-stationary, random walk process for the ZAR/USD and BRL/USD. The KPSS test at levels indicated a random walk process for the RUB/USD prior to

and during QE, however a non-random process is indicated by the KPSS test post QE. For the INR/USD, the KPSS test at levels indicates a non-random walk prior QE, a random walk during QE and a non-random walk post QE. The KPSS test at levels for the CNY/USD indicates a random walk process prior to QE and a change in state to a stationary process during and post QE.

The KPSS test for the ZAR/EUR at levels showed a random walk process during and post QE, for the BRL/EUR KPSS test at levels, a stationary process was shown prior to, during and post QE. For the RUB/EUR KPSS test at levels, a non-stationary process was found prior to QE, and a non-random walk process during and post QE. The INR/EUR KPSS test at levels showed a non-stationary process prior to and during QE, contrasted by a stationary process post QE. The CNY/EUR KPPS test at levels indicates a non-stationary, random walk process, prior to and during QE, but a stationary, non-random walk post QE.

When considering the U.S. currency cross pairs at first difference, the PP test shows that the ZAR/USD, INR/USD and BRL/USD is a non-random walk generating process (Table 3) at the 5% significance level, prior, during and post U.S. QE. The RUB/USD first difference PP tests show a random walk process prior to QE, however a non-random walk process during and post U.S. QE (Table 3). The CNY/USD first difference PP test shows (Table 3) shows a stationary generating process prior to and during U.S. QE, however a non-stationary process post U.S. QE (Table 3.). The ADF test at first difference indicated a non-random process for the ZAR/USD, BRL/USD and INR/USD prior to, during and post QE. The ADF test at first difference for the RUB/USD showed a change in market efficiency state; prior to QE the test showed a non-stationary process, during and post QE, a non-random walk process was shown. The ADF test at first difference for the CNY/USD indicated a non-random walk process prior to and during QE, but a random state after QE. The KPSS test at first difference fails to reject the null hypothesis for

all ten currency pairs and the currency pairs at first difference are found to be stationary or non-random generating processes.

When considering the Euro currency cross pairs, the PP test at first difference showed that the ZAR/EUR, BRL/EUR, RUB/EUR, INR/EUR and CNY/EUR followed a random walk post E.U QE but did not do so prior to and during QE.

The ADF test for Euro currency cross pairs, at first difference indicated that the ZAR/EUR, BRL/EUR, INR/EUR and CNY/EUR followed a random walk process post QE but did not do so during and prior to QE. The RUB/EUR ADF test displayed a stationary process for all time periods at first difference.

The KPSS test for Euro currency cross pairs, at first difference indicated that the ZAR/EUR, BRL/EUR and INR/EUR was a stationary generating process for all time periods considered. The RUB/EUR KPSS test at first difference indicated a stationary process prior and during QE, and a random walk after QE. The KPSS test at first difference for the CNY/EUR displayed a stationary process prior to and during QE, followed by a random walk after QE.

11.3. Autocorrelation Tests

The randomness of the time series can be evaluated by determining to what degree a previous price determines the future price in the series. The ACF and PACF plots are indicators of the time series randomness. The autocorrelation of the series describes how correlated or related one price point is to another, at one period away. The greater the autocorrelation and partial autocorrelation functions, the greater the influence the previous data point has in explaining the next data point.

The related ACF and PACF plots for all the currency pairs investigated can be seen in the appendix of the research report. Plots for the ZAR/USD, BRL/USD, RUB/USD, INR/USD and CNY/USD can be seen in Appendices C1-C6, D1-D6, E1-E6, F1-F6, G1-G6. ACF and PACF plots for the ZAR/EUR, BRL/EUR, RUB/EUR, INR/EUR and CNY/EUR can be seen in Appendices H1-H6, I1-I6, J1-J6, K1-K6 and L1-L6.

When considering U.S. QE, the autocorrelation tests at levels, the tests show that autocorrelation and partial autocorrelation increases during the quantitative easing period. The rate of decay of the autocorrelation function and partial autocorrelation functions is reduced during quantitative easing versus the time period prior to it, as well as post it. The implies that the respective currency pairs could be explained to a larger degree by previous data points.

The Euro currency pair exchange rate data at levels stands in contrast to the U.S. data. The ZAR/EUR, BRL/EUR, RUB/EUR, INR/EUR and CNY/EUR show reduced autocorrelation in the ACF and PACF plots during QE when contrasted against the period prior to and post it. The rate of decay for E.U. currency pair autocorrelation plots during E.U. QE is greater than the period before and after it. This would imply an improvement in market efficiency during E.U. QE.

11.4. Variance Ratio Tests

Each variance ratio step is investigated within the dataset. That is, considering the ratio of the variance of one data point to the next. Each incremental variance ratio step is to be uncorrelated with the next for a process to be considered a random walk or efficient.

The null hypothesis for the variance ratio test is one of the data set being a martingale or a stochastic process which consists of random variables located in a given probability space. The results of the variance ratio tests for all currency pairs studied are shown in Table 5.

		Max |z|		Wald (Chi-Square)	
	Period	**Value**	**P-Value**	**Value**	**P-Value**
	Prior QE	1.386360	0.515400	2.568930	0.632300
	QE	0.909365	0.835500	1.392349	0.845500
ZAR/USD	Post QE	2.069832	0.145200	5.044409	0.282800
	Prior QE	1.570910	0.389900	4.408017	0.353600
	QE	1.249077	0.613700	5.449314	0.244200
BRL/USD	Post QE	1.036225	0.760000	1.351613	0.852600
	Prior QE	1.877125	0.220900	6.262668	0.180400
	QE	3.224874	0.005000	17.157020	0.001800
RUB/USD	Post QE	1.290771	0.583800	2.762722	0.598300
	Prior QE	2.330321	0.076800	10.530900	0.032400
	QE	0.979795	0.795100	1.014868	0.907500
INR/USD	Post QE	1.032109	0.762700	3.258098	0.515600
	Prior QE	2.084564	0.140400	7.799156	0.099200
	QE	2.209796	0.104100	8.418709	0.077400
CNY/USD	Post QE	0.956913	0.808700	5.117099	0.275500
	Prior QE	0.258481	0.998300	2.198788	0.699300
	QE	1.442289	0.476100	4.694833	0.320100
ZAR/EUR	Post QE	0.877260	0.616000	0.778085	0.677700
	Prior QE	1.043424	0.755400	2.629282	0.621600
	QE	0.518471	0.975400	0.519725	0.971600
BRL/EUR	Post QE	1.488867	0.254400	2.344219	0.309700
	Prior QE	2.667280	0.030200	23.017500	0.000100
	QE	23.017500	0.000100	6.084923	0.192900
RUB/EUR	Post QE	1.449763	0.272600	2.125951	0.345400
	Prior QE	0.655502	0.943400	3.275636	0.512800
	QE	1.286477	0.586900	2.165934	0.705300
INR/EUR	Post QE	1.369381	0.312600	1.893312	0.388000
	Prior QE	1.440201	0.477500	9.853132	0.043000
	QE	1.783032	0.266600	3.504931	0.477100
CNY/EUR	Post QE	1.186857	0.415200	1.559989	0.458400

Table 5. Variance Ratio Test output results.

When considering Max |z| values, the ZAR/USD, BRL/USD, INR/USD, CNY/USD, ZAR/EUR, BRL/EUR, INR/EUR and CNY/EUR fail to reject the null hypothesis of a martingale or efficient market for all time periods considered. That is prior to the respective QE period, during QE and post QE. The null hypothesis is rejected for the RUB/USD and RUB/EUR during QE. Indicating a non-random generating process during QE or an inefficient market during QE.

When considering Wald (Chi-Square) statistics, the null hypothesis fails rejection upon testing the ZAR/USD, BRL/USD, CNY/USD, ZAR/EUR, BRL/EUR and INR/EUR, implying an efficient market for these currency pairs considered. The test suggests a non-random and inefficient market when considering the RUB/USD during QE, and the INR/USD, RUB/EUR, CNY/EUR prior QE.

The RUB/USD is the only currency pair to display an efficient market prior to QE, an efficient market during QE and an inefficient market post QE when considering the variance ratio test (Table 5).

11.5. Johansen Cointegration Equation (CE) Testing

In an efficient market, the forward exchange rate is expected to be an unbiased predictor of future spot exchange rates (Hallwood & MacDonald, 2000). Therefore, a long run relationship between the forward exchange rate and spot exchange rate at time t+3, for example should exist.

Cointegration of variables suggests that the variables have a long run relationship and move together at some point in the long run. They have a long run relationship. The Johansen test of cointegration is seen as a robust test for investigating long run relationships between variables. The Engle-Granger approach follows a two-step estimation approach. The first step generates residuals and the second step estimates a regression of the first differenced residuals on the same lagged residuals, resulting in errors from the first step being transferred to the second. The Johansen methodology is superior by testing for the presence of multiple cointegrating vectors through the largest canonical correlations (Bilgili, 1998). The Engle-Granger approach may result in inconclusive outcomes whereas the Johansen approach does not (Bilgili, 1998). Monte Carlo simulations suggest that the Johansen integration test performs better than Engle-Granger method

(Bilgili, 1998). The Johansen cointegration test is seen as a robust technique for market efficiency testing in the FX market (Matebejana, Motlaleng & Juana, 2017).

Before conducting the cointegration tests, both data sets, being the spot rates (S_t) and corresponding forward rates (S_{t+3}) were found to be of order of integration 1, where (S_{t+3}) is the 3 month forward rate and is of a monthly frequency.

Table 6 shows the results from the Johansen cointegration tests between the spot currency pairs and their 3 month forward rates. The ZAR/USD, ZAR/EUR and RUB/USD shows 1 cointegrating equation during QE but does not prior to or after QE. This suggests that the ZAR/USD, ZAR/EUR and RUB/USD were efficient during QE but not prior to or after it.

The INR/USD shows 1 cointegrating relationship during and after QE but not prior to it . Indicating that the INR/USD became an efficient market during QE and remained as such after QE. The CNY/USD and RUB/EUR shows 1 cointegrating relationship prior to QE. Suggesting that the CNY/USD and RUB/EUR were efficient prior to QE but were inefficient during and post it. The BRL/EUR shows 1 cointegrating relationship post QE. Indicating that the currency pair was considered an efficient market post QE.

The INR/EUR shows 1 cointegrating relationship prior to and during QE and 2 cointegrating relationships after QE. Indicating an efficient market throughout all time periods considered.

The BRL/USD and CNY/EUR show no cointegrating relationships.

11.5.1 U.S. Currency Cross Pairs Johansen Cointegration Test

The Johansen cointegration test for the 5 U.S. currency cross pairs considered, namely the ZAR/USD, BRL/USD, RUB/USD, INR/USD and CNY/USD in Appendices M1- M3 show that

no cointegrating relationships existed prior to QE. During QE, the number of cointegrating relationships increased to at most 1. After QE, the number of cointegrating relationships increased to at most 3 (Appendix M3). In an efficient market it is assumed that 1 currency pair should not be predicted by another and no cointegrating relationship should exist.

11.5.2. E.U. Currency Cross Pairs Cointegration Test

The Johansen system cointegration test revealed that 1 cointegrating relationship existed prior to and during QE (Appendix N1-N2). There was not a large enough sample size to conduct the Johansen cointegration test post E.U. QE. However, the Engle-Granger single equation cointegration test for the period post European QE revealed that no cointegrating relationships existed (Appendix N3).

		Hypothesised No. CE'S			
		None		At most 1	
	Period	**0.05 CV**	**Prob.**	**0.05 CV**	**Prob.**
	Prior QE	15.494710	0.071000	3.841147	0.076500
	QE	15.494710	0.040800	3.841466	0.298600
ZAR/USD	Post QE	15.494710	0.308700	3.841466	0.080000
	Prior QE	15.494710	0.203800	3.841466	0.095300
	QE	15.494710	0.977200	3.841466	0.937600
BRL/USD	Post QE	15.494710	0.432600	3.841466	0.163200
	Prior QE	15.494710	0.577900	3.841466	0.515700
	QE	15.494710	0.043300	3.841466	0.496400
RUB/USD	Post QE	15.494710	0.175900	3.841466	0.037100
	Prior QE	15.494710	0.273600	3.841466	0.595600
	QE	15.494710	0.005200	3.841466	0.492500
INR/USD	Post QE	15.494710	0.002400	3.841466	0.062300
	Prior QE	15.494710	0.027700	3.841466	0.118000
	QE	15.494710	0.086300	3.841466	0.101800
CNY/USD	Post QE	15.494710	0.249000	3.841466	0.254600
	Prior QE	15.494710	0.465600	3.841466	0.179300
	QE	15.494710	0.000700	3.841466	0.004700
ZAR/EUR	Post QE	15.494710	0.639800	3.841466	0.277100
	Prior QE	15.494710	0.508200	3.841466	0.171500
	QE	15.494710	0.857900	3.841466	0.851400
BRL/EUR	Post QE	15.494710	0.000000	3.841466	0.509900
	Prior QE	15.494710	0.016500	3.841466	0.417400
	QE	15.494710	0.305100	3.841466	0.147900
RUB/EUR	Post QE	15.494710	0.342000	3.841466	0.053400
	Prior QE	15.494710	0.000600	3.841466	0.057100
	QE	15.494710	0.000100	3.841466	0.179600
INR/EUR	Post QE	15.494710	0.000300	3.841466	0.006900
	Prior QE	15.494710	0.164900	3.841466	0.157100
	QE	15.494710	0.078300	3.841466	0.190800
CNY/EUR	Post QE	15.494710	0.342000	3.841466	0.053400

Table 6. Johansen cointegration equation test results.

11.6. Uncovered Interest Parity (UIP)Testing

UIP is tested by investigating the relationship between the difference between the spot rate at t=0 and the forward rate at t+3, and whether this difference can be explained by the interest rate differential between the two countries concerned. The interest rate being the 3 month treasury bill per respective region in the period concerned.

The regression equation would be of the form (Mukherjee, 2018):

$$\ln(S_{t+3}) - \ln(S_t) = \alpha + \beta\left(i_{foreign} - i_{U.S.}\right) + \varepsilon_{t+1}$$

Where, $\alpha = 0$ and $\beta = 1$

UIP was found not to hold for all currency pairs tested for all time periods concerned, as seen in Table 7. This implies that all currency pairs tested are not strong form efficient.

Evidence of the forward discount bias can be seen in the slope coefficient or β, depressing β such that is not unity, sometimes becoming negative and violating the UIP condition.

	Period	α	β
	Prior QE	0.000918	0.002006
ZAR/USD	QE	0.003136	0.001943
	Post QE	0.006246	0.001202
	Prior QE	0.014075	0.001072
BRL/USD	QE	-0.004595	0.002426
	Post QE	-0.000853	0.002010
	Prior QE	-0.003512	0.003634
RUB/USD	QE	-0.007021	0.003127
	Post QE	0.003288	0.001487
	Prior QE	0.002443	0.001505
INR/USD	QE	-0.003290	0.002673
	Post QE	0.022008	-0.002320
	Prior QE	-0.011988	-0.000153
CNY/USD	QE	0.001919	0.000524
	Post QE	0.002120	0.002648
	Prior QE	0.007363	0.001226
ZAR/EUR	QE	0.016697	0.000540
	Post QE	0.026673	-0.002063
	Prior QE	-0.010462	0.002604
BRL/EUR	QE	0.007999	0.001651
	Post QE	0.002527	0.002995
	Prior QE	-0.000593	0.002261
RUB/EUR	QE	0.007366	0.001889
	Post QE	0.004615	0.002961
	Prior QE	-0.004773	0.002649
INR/EUR	QE	0.016237	0.000035
	Post QE	0.035998	-0.004532
	Prior QE	-0.006690	0.002730
CNY/EUR	QE	0.011869	-0.000849
	Post QE	0.009244	-0.001429

Table 7- Uncovered Interest Parity test results. The related test outputs for the following currency pairs: ZAR/USD, BRL/USD, RUB/USD, INR/USD, CNY/USD, ZAR/EUR, BRL/EUR, RUB/EUR, INR/EUR and CNY/EUR. Can be seen in the following corresponding appendices:C7-C9, D7-D10, E7-E9, F7-F9, G7-G9, H7-H9, I7-I9, J7-J9, K7-K9, L7-9.

11.7. Results Summary

Descriptive statistics of the data revealed that all 5 U.S. currency cross pairs did not follow a log-normal distribution during QE and all 5 Euro currency cross pairs followed a log-normal distribution during and post QE.

The unit root test results are summarized in Tables 8, 9, 10 and 11. The unit root tests show that all currency pairs largely follow a random walk at levels but tend not to at first difference. Unit root testing at first difference reveals whether a stationary series is achieved, and if so, integrated of order 1 or I (1). Therefore, the test of weak form efficiency is focused on the data at levels.

	US Cross Pairs at Levels		
	Prior QE	During QE	Post QE
PP			
ZAR/USD	R	R	R
BRL/USD	R	R	R
RUB/USD	R	R	R
INR/USD	R	R	R
CNY/USD	R	R	R
ADF			
ZAR/USD	R	R	R
BRL/USD	R	R	R
RUB/USD	R	R	R
INR/USD	R	R	R
CNY/USD	R	R	R
KPSS			
ZAR/USD	R	R	R
BRL/USD	R	R	R
RUB/USD	R	R	N
INR/USD	N	R	N
CNY/USD	R	N	N

Table 8- Unit Root Results. R (Random Walk). N (Non-Random).

	US Cross Pairs at 1st Difference		
	Prior QE	During QE	Post QE
PP			
ZAR/USD	N	N	N
BRL/USD	N	N	N
RUB/USD	R	N	N
INR/USD	N	N	N
CNY/USD	N	N	R
ADF			
ZAR/USD	N	N	N
BRL/USD	N	N	N
RUB/USD	R	N	N
INR/USD	N	N	N
CNY/USD	N	N	R
KPSS			
ZAR/USD	N	N	N
BRL/USD	N	N	N
RUB/USD	N	N	N
INR/USD	N	N	N
CNY/USD	N	N	N

Table 9-Unit Root Test Results. R (Random Walk). N (Non-Random Walk).

EU Cross Pairs at Levels			
	Prior QE	During QE	Post QE
PP			
ZAR/EUR	R	R	N
BRL/EUR	R	R	R
RUB/EUR	R	R	R
INR/EUR	R	R	R
CNY/EUR	R	R	R
ADF			
ZAR/EUR	R	R	R
BRL/EUR	R	R	R
RUB/EUR	R	R	R
INR/EUR	R	R	N
CNY/EUR	R	R	R
KPSS			
ZAR/EUR	N	R	R
BRL/EUR	R	R	R
RUB/EUR	N	R	R
INR/EUR	N	R	R
CNY/EUR	R	R	N

Table 10- Unit Root Test Results. R(Random). N(Non-Random)

EU Cross Pairs at 1st Difference			
	Prior QE	During QE	Post QE
PP			
ZAR/EUR	N	N	R
BRL/EUR	N	N	R
RUB/EUR	N	N	R
INR/EUR	N	N	R
CNY/EUR	N	N	R
ADF			
ZAR/EUR	N	N	R
BRL/EUR	N	N	R
RUB/EUR	N	N	N
INR/EUR	N	N	R
CNY/EUR	N	N	R
KPSS			
ZAR/EUR	N	N	N
BRL/EUR	N	N	N
RUB/EUR	N	N	R
INR/EUR	N	N	N
CNY/EUR	N	N	R

Table 11- Unit Root Test Results. R (Random). N (Non-Random).

The KPSS unit root test produced slightly different results to the PP and ADF tests. The null hypothesis of the ADF and PP tests is the presence of a unit root, indicating a non-stationary, random walk process (Pantelis & Zehtabchi, 2008). The null hypothesis of the KPSS test is a stationary, non-random generating process (Nielsen, 2005). The PP and ADF test results are more similar when contrasted against the KPSS test.

At levels, the RUB/USD and the INR/USD displayed a change in process generating state (Table 8 KPSS test) post QE. The CNY/USD changed generating state during and post QE (Table 8 KPSS test).

E.U PP and ADF unit root tests at levels indicated that the currency pairs display largely random generating processes. The E.U PP and ADF tests at levels indicate a change in process generating

state for the ZAR/EUR and INR/EUR (Table 10). Both pairs displayed non-random generating processes post QE versus random generating processes during and prior QE. The E.U KPSS test at levels shows a change in state generating process for the INR/EUR, RUB/EUR, CNY/EUR and ZAR/EUR (Table 10).

Unit root testing was conducted to test the efficiency of the Namibian FX market (Engelbrecht, Mabakeng, Peyavali & Sheefeni, 2014). The study used monthly data from January 1993 to December 2011. The results confirm market efficiency in Namibia's FX market.

Weak form efficiency was investigated for the exchange rates of 30 countries forming part of the Organisation for Economic Cooperation and Development (OECD) (Ibrahim, Long, Ghani & Salleh, 2011). Augmented Dickey-Fuller (ADF), Philip-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests were conducted to investigate whether future price movements could be speculated based on historic time series data. Weekly data for the period 2000 to 2007 was tested. Exchange rates for all 30 countries tested were found to be weak form efficient.

The autocorrelation tests for U.S. QE showed that autocorrelation functions and partial autocorrelation functions increased during QE and the rate of decay of these plots decreased when contrasted against the periods prior to and after QE. This suggest that currency pair data could be explained to a larger degree by previous data points during QE. Suggesting reduced efficiency during U.S QE.

Autocorrelation tests for E.U currency cross pairs show reduced autocorrelation and partial autocorrelation during QE. The rate of decay is greater during QE, implying an increase in market efficiency during E.U QE.

The variance ratio tests indicated that the ZAR/USD, BRL/USD, INR/USD, CNY/USD, ZAR/EUR, BRL/EUR, INR/EUR and CNY/EUR cross pair data failed to reject the null hypothesis of an efficient market and could be considered as efficient prior QE, during QE and post QE. The variance ratio tests for the RUB/USD and RUB/EUR were found to be non-random generating processes and inefficient during QE.

Kumar & Kamaiah (2016) tested weak form market efficiency of BRICS countries for the period April 1994 to September 2014. The tests included variance ratio tests. The variance ratio tests rejected weak form efficiency for all 5 countries.

Weak form market efficiency of seven South Asian countries was also tested by Noman & Ahmed (2008) from 1985 to 2005. Unit root and variance ratio tests were used to test the RWH. The foreign exchange rates of these seven countries were found to not be serially correlated and were found to be weak form efficient. The variance ratio test results in this research aligns with that of Noman & Ahmed (2008).

The presence of a cointegrating equation between spot and 3 month forward rates per currency pair indicates a long run relationship and an efficient market. The CNY/USD and RUB/EUR indicated 1 cointegrating equation prior QE. The INR/USD, ZAR/USD, ZAR/EUR and RUB/USD indicated 1 cointegrating equation during QE. The BRL/EUR indicated 1 cointegrating equation post QE. The INR/EUR showed a minimum of 1 cointegrating equation throughout all time periods. The BRL/USD and CNY/EUR indicated no cointegrating relationships. Mukherjee (2018) finds that the random walk hypothesis does not hold for BRICS country monthly exchange rate data against the United States dollar, using Johansen cointegration procedure. The results from this research stand in contrast to that of Mukherjee (2018).

When considering all time periods investigated, the uncovered interest parity condition did not hold for any of the 10 currency pairs tested. This result is in line with that of Mukherjee (2018). This implies that the relationship between the spot and forward exchange rates could not be explained by the interest rate differential between the two countries concerned. Suggesting that all 10 currency cross pairs are not strong form efficient.

In summary, the unit root tests indicated that the 10 currency pairs investigated at levels, were weak form efficient during QE. The autocorrelation tests however indicated increased autocorrelation during QE for U.S. pairs and reduced autocorrelation for EU pairs during QE. The variance ratio tests indicated that 8/10 currency pairs were market efficient throughout all time periods considered. According to the variance ratio test, only the RUB/USD and RUB/EUR displayed a non-random generating process during QE. Cointegration testing revealed that 5/10 currency pairs displayed 1 cointegrating relationship during QE and were semi-strong form efficient during QE. Running the cointegration tests for a system of the 5 U.S. currency pairs revealed that no cointegrating equations existed prior QE, but at most 1 existed during QE, indicating some semi-strong inefficiency during QE, as this suggests that movements in 1 currency pair could be explained by another. The cointegration test for the 5 E.U cross pair system indicated no cointegrating equations during QE, indicating semi-strong efficiency for E.U pairs during QE. The UIP testing revealed that of the 10 pairs tested were not strong form efficient.

12. Implications of an inefficient forex market for BRICS countries

An inefficient forex market would imply that there exists exploitable information which gives rise to arbitrage opportunities. Suggesting that speculators can make abnormal profits by make use of historical information. An inefficient forex market would support the argument that forex cartels

exist and that rigging of the South African Rand is possible by key market participants constituting a large proportion of the volume of currency traded.

Considering that BRICS countries' economies are highly dependent on exports, exchange rate fluctuations are a key concern for these countries. The strengthening and depreciation of these countries' currencies ties directly into the competitiveness of their exports. Inefficiency in the FX market may force governments to intervene to reduce exchange rate volatility and evaluate policies which can be used to curb it.

13. Conclusions

In concluding this research report, certain analysis will be highlighted, and the research questions posed initially will be answered.

In determining the state of market efficiency prior to, during and post European and U.S quantitative easing periods for BRICS currencies versus the Euro and the United States Dollar, a procedure was followed as outlined in the methodology of this report. To determine whether or not there were any changes in the state of market efficiency prior to, during and post quantitative easing the same methodology was followed.

Preliminary tests of market efficiency were conducted through unit root tests. These included the PP, ADF and KPSS unit root tests, of which the PP test was considered to be the most powerful. The PP unit root test at levels indicated that all 10 currency pairs followed a random walk during QE.

The RUB/EUR and RUB/USD underwent a change in efficiency state according to the variance ratio tests. RUB/USD was found to be a random walk prior QE, an inefficient generating process

during QE and a random walk generating process post QE. The RUB/EUR was found to follow a non-random generating process prior and during QE and a random walk after QE.

The correlogram plots indicating autocorrelation and partial autocorrelation showed that autocorrelation increased during QE for U.S currency cross pairs during QE and declined for E.U currency cross pairs during QE.

Variance ratio tests followed. The variance ratio tests indicated that 8/10 currency pairs were market efficient throughout all time periods considered. The Russian Rubble relative to the U.S Dollar and the Euro was found to be an inefficient market during QE.

Thereafter, cointegration testing revealed that 5/10 currency pairs displayed 1 cointegrating relationship during QE and were semi-strong form efficient during QE.

Running the cointegration tests for a system of the 5 U.S currency pairs revealed that no cointegrating equations existed prior QE, but 1 existed during QE. Indicating some semi-strong inefficiency during QE.

The cointegration test for the 5 E.U cross pair system indicated no cointegrating equations during QE. Indicating semi-strong efficiency for E.U currency pairs during QE.

UIP testing was conducted next. UIP testing revealed that of the 10 pairs tested, none were found to be strong form efficient. That is, the difference between the forward and spot exchange rate could not be explained by the interest rate differential between the two countries concerned.

The Johansen cointegration tests also showed a change in market efficiency state during the time periods considered. The ZAR/USD, ZAR/EUR and RUB/USD changed market efficiency state during QE versus the periods prior to QE and after it. The INR/USD, CNY/USD and RUB/EUR

changed market efficiency state during QE versus the period prior to it. The BRL/EUR indicated a change in market efficiency state post QE.

The empirical evidence in this research report suggests that U.S and European quantitative easing did in fact coincide with a change in the state of market efficiency of certain, but not all BRICS currency pairs relative to the Euro and U.S Dollar during the time periods investigated.

14.Recommendations

The research shows a decline in market efficiency for U.S cross pairs during QE. It is evident that the BRICS cross-pairs are not efficient, as evident from the UIP condition not holding. In light of this, it is recommended that government intervention is required to engage with the U.S to limit prolonged and excessive QE which could cause further reduced efficiency of BRICS FX markets. Mispricing of currencies results in sub-optimal resource allocation by investment portfolios.

The UIP testing does not consider transaction costs and assumes perfect mobility of capital. These factors would need to be incorporated in the UIP regression equation as additional variables in the future. The effect of risk perception by market participants was not considered and would need to be captured in the future.

Further research on this topic would need to focus in on isolating quantitative easing as a variable and testing whether it is solely responsible for causing inefficiencies in markets and does not merely coincide with a change in market efficiency state. This would require complex econometric models which can directly pinpoint the cause of a change of market efficiency state.

15. List of references

Ahmad, R., Rhee, S.G., Wong, Y.M., 2012. Foreign exchange market efficiency under recent crisis: Asia-Pacific focus. *Journal of International Money and Finance, 31* (2012), 1574-1592. Retrieved online: 10.1016/j.jimonfin.2012.02.016

Akram, F., Rime, D., Sarno, L., 2005. Arbitrage in the Foreign Exchange Market: Turning on the Microscope. *Norges Bank Research Department.* Retrieved online: https://www.norges-bank.no/globalassets/upload/import/publikasjoner/arbeidsnotater/pdf/arb-2005-12.pdf

Almudhaf, F., 2014. Testing for random walk behaviour in CIVETS exchange rates. *Applied Economics Letters,21* (1), 60-63. Retrieved online: http://dx.doi.org/10.1080/13504851.2013.839856

Amelot, L.M.M., Ushad, S.A, Lamport, M., 2017. Testing the Efficient Market Hypothesis in an Emerging Market: Evidence from Forex Market in Mauritius. Scientific Research Publishing. Theoretical Economic letters, 2017, 7, 2104-2122.

Aron. J., 1997. Foreign Exchange Market Efficiency Tests in South Africa. *Centre for the Study of African Economies, Department of Economics, University of Oxford, England.* Retrieved online: https://pdfs.semanticscholar.org/d05b/9f1184dd0761d385ddb6e5af0e1f554d3120.pdf

Bilgili, F., 1998. Stationarity and cointegration tests: Comparison of Engle-Granger and Johansen Methodologies. *Erciyes University of Economics and Administrative Sciences.* Retrieved online: https://mpra.ub.uni-muenchen.de/75967/1/MPRA_paper_75967.pdf

BIS, 2016. Triennial Central Bank Survey Foreign Exchange Turnover in April 2016. *Bank for International Settlements.* Retrieved online: https://www.bis.org/publ/rpfx16fx.pdf

Blaire-Franch, J., Contreras, D., 2004. Ranks and signs-based multiple variance ratio tests, Working paper, *Department of Economic Analysis, University Valencia*

Blake, D., Beenstock, M., Brasse, V., 1986. The Performance of U.K. Exchange Rate Forecasters. *Royal Economic Society, 96* (384), 986-999. Retrieved online: https://www.jstor.org/stable/pdf/2233169.pdf?ab_segments=0%2Fdefault-2%2Fcontrol&refreqid=search%3A9d4ace7b338b3236faf6f6b58b0c84a5

CFA Institute, 2019. Currency Exchange Rates. Retrieved online: https://www.cfainstitute.org/membership/professional-development/refresher-readings/2019/currency-exchange-rates

Charles, A., Darné, O., 2009. Testing for random walk behavior in Euro exchange rates. *Economie Internationale.* Retrieved online: https://www.cairn.info/revue-economie-internationale-2009-3-page-25.htm#

Chaboud, A.P., Chiquoine, B., Hjalmarsson, E., Vega, C., 2014. Rise of the Machines: Algorithmic Trading in the Foreign Exchange Market. *Journal of Finance, 69*(5), 2045-2084. Retrieved online: http://www.smallake.kr/wp-content/uploads/2014/06/jofi12186.pdf

Chen, J.H., 2008. Variance Ratio Tests of Random Walk Hypothesis of The Euro Exchange Rate. *International Business & Economics Research Journal, (7)*, 12. 97. Retrieved online: https://clutejournals.com/index.php/IBER/article/download/3318/3366

Chen, W.W., Deo, R.S., 2006. The variance ratio statistic at large horizons. *Econometric Theory*, vol 22, p 206-234

Chow, K.V., Denning, K.C., 1993. A simple multiple variance ratio test. *Journal of Econometrics*, vol. 58, p.385-401

Crosoer, D. (2018, June). U.S. rate cycle could dampen SA good-news cycle. *Finweek*,28. Retrieved online: http://0-search.ebscohost.com.innopac.wits.ac.za/login.aspx?direct=true&db=bsu&AN=130037209&site=ehost-live&scope=site

Czech, K.A., Waszkowski, A., 2012. Foreign Exchange Market Efficiency. Empirical Results for the USD/EUR Market. *Financial Internet Quarterly e-Finance.* Retrieved online: http://cejsh.icm.edu.pl/cejsh/element/bwmeta1.element.cejsh-250ce5d0-f5c3-46b2-a0a3-b584f04f3c52/c/223.pdf-1

De Grauwe, P., Kaltwasser, P.R., 2006. A Behavioral Model of the Exchange Rate with Many Forecasting Rules. Retrieved online: https://core.ac.uk/download/pdf/34312569.pdf

Dunis, C.L., Williams, M., 2002. Modelling and Trading the EUR/USD Exchange Rate: Do Neural Network Models Perform Better? *Liverpool Business School and CIBEF*. Retrieved online: https://www.researchgate.net/publication/241483870_Modelling_and_Trading_the_EURUSD_Exchange_Rate_Do_Neural_Network_Models_Perform_Better

Duke, 2019. *ARIMA models for time series forecasting*. Retrieved online: https://people.duke.edu/~rnau/411arim3.htm

Economist, 2017. Why the Federal Reserve should keep its balance sheet large. Retrieved online: https://www.economist.com/finance-and-economics/2017/04/12/why-the-federal-reserve-should-keep-its-balance-sheet-large

Engelbrecht, M., Mabakeng, P., Peyavali, J., Sheefeni, S., 2014. Examining the Weak Form Efficiency in Foreign Exchange Market in Namibia. *International Review of Research in Emerging Markets and the Global Economy*. Retrieved online: http://globalbizresearch.org/files/id_6015_irrem_mukela-engelbrecht-peter-mabakeng_-johannes-peyavali-sheefeni-sheefeni-87197.pdf

Eun, C.S., Resnick, B.G., 2009. *International Financial Management.* New York, NY: McGraw-Hill.

Evans, D.D.M., Lyons, K.R. 2002. Order Flow and Exchange Rate Dynamics. *Journal of Political Economy*. Retrieved online: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.407.4667&rep=rep1&type=pdf

Fama, F.E., 1970. Efficient Capital Markets: A Review of Theory and Empirical Work. *The Journal of Finance*, Vol. 25, No. 2, Papers and Proceedings of the Twenty Eighth Annual Meeting of the American Finance Association New York, pp. 383-417. Retrieved online:

https://0-www-jstor-org.innopac.wits.ac.za/stable/pdf/2325486.pdf?ab_segments=0%2Fdefault-2%2Fcontrol&refreqid=search%3Adf4d55a64db07ce107396e9dd134ba8d

Fama, F.E., 1984. Forward and spot exchange rates. *Journal of Monetary Economics.* Retrieved online: https://0-doi-org.innopac.wits.ac.za/10.1016/0304-3932(84)90046-1

Fama, F.E., Litterman, R., 2012. An Experienced View on Markets and Investing. Financial Analysts Journal. Retrieved online: https://www.jstor.org/stable/41714292

Ferrari, M., Kearns., J., Schrimpf, A., 2017. Monetary Policy's Rising FX impact in the era of ultra-low rates. *Bank of International Settlements Working Papers.* Retrieved online: https://www.bis.org/publ/work626.pdf

Flood, D.M., 1991. Microstructure Theory and the Foreign Exchange Market. *Federal Reserve Bank of St. Louis.* Retrieved online: https://files.stlouisfed.org/files/htdocs/publications/review/91/11/Microstructure_Nov_Dec1991.pdf

Gradojević, N., Djaković, V., Andjelić, G., 2010. Random Walk Theory and Exchange Rate Dynamics in Transition Economics. *Panoeconomicus, 3,*303-320. Retrieved online: 10.2298/PAN1003303G

Goodhart, C., 1988. The Foreign Exchange Market: A Random Walk With a Dragging Anchor. The London School of Economics. Retrieved online: https://www.jstor.org/stable/2553908

Hallwood, C.P., MacDonald, R. 2000. International Money and Finance. Oxford: Wiley Blackwell publishers.

Hartmann, P., Smets, F., 2018. The First 20 Years of the European Central Bank: Monetary Policy. *Brookings Papers on Economic Activity.* Retrieved online: https://www.brookings.edu/wp-content/uploads/2018/09/BPEA_Fall2018_The-First-20-Years-of-the-European-Central-Bank.pdf

Hasbrouck, J., Saar, G., 2013. Low-latency trading. Journal of Financial Markets, 16, 646-679. Retrieved online: https://doi.org/10.1016/j.finmar.2013.05.003

Henriksson, R., Merton, R., 1981. On Market timing and investment performance II. Statistical procedures for evaluating forecasting skills. Journal of Business, 54, 513-533.

Hradzil, K., Chung, D., 2010. Liquidity and market efficiency: a large sample study. *Journal of Banking and Finance.* Retrieved online: https://econpapers.repec.org/article/eeejbfina/v_3a34_3ay_3a2010_3ai_3a10_3ap_3a2346-2357.htm

Ibrahim, J., Long, Y., Ghani, H.A., Salleh, M.IS., 2011. Weak-Form Efficiency of Foreign Exchange Market in the Organisation for Economic Cooperation and Development Countries: Unit Root Tests. International Journal of Business and Management, 6 (6), 55-61. Retrieved online: 10.5539/ijbm.v6n6p55

Imam, A., Habiba, D., Atanda, B.T., 2016. On Consistency of Tests for Stationarity in Autoregressive and Moving Average Models of Different Orders. *American Journal of Theoretical and Applied Statistics. 5* (3), 146-153. Retrieved online: https://pdfs.semanticscholar.org/f128/d0d72f70d0a94ecf329a9363fc1ef0abfd9e.pdf

Ismail, A., 2017. Citibank to pay R69.5 m in rigging scandal. *Fin24.* Retrieved online: https://www.fin24.com/Companies/Financial-Services/just-in-citibank-to-pay-r69m-in-rand-rigging-scandal-20170220

James, J., Marsh, W.I., Sarno, L., 2012. Handbook of Exchange Rates. New Jersey: John Wiley & Sons, Inc.

Joyce, M., Miles, D., Scott, A., Vayanos, D., 2012. Quantitative Easing and Unconventional Monetary Policy – An Introduction. *The Economic Journal.* Retrieved online: http://personal.lse.ac.uk/vayanos/Papers/QEUMCI_EJ12.pdf

Karemera, D., Ojah, K., Cole, A.J., 1999. Random Walks and Market Efficiency Tests: Evidence From Emerging Equity Markets. *Review of Quantitative Finance and Accounting.* Retrieved online: https://link.springer.com/content/pdf/10.1023%2FA%3A1008399910942.pdf

Khomo, M.M., Aziakpono, M.J., 2016. The behaviour of the real effective exchange rate of South Africa: is there a misalignment? *Economic Research Southern Africa.* Retrieved online: https://econrsa.org/system/files/publications/working_papers/working_paper_644.pdf

Katusiime, L., Shamsuddin, A., Agbola, F.W., 2014. Foreign exchange market efficiency and profitability of trading rules: Evidence from a developing country. International Review of Economics and Finance. Retrieved online: https://doi.org/10.1016/j.iref.2014.10.003

King, R.M., Massoud, N., Song, K., 2013. How Does Bank Trading Activity Affect Performance? An Investigation Before and After the Crisis. Retrieved online: https://www.fdic.gov/bank/analytical/cfr/bank-research-conference/annual-13th/king.pdf

Kitamura, Y., 2016. Simple Measures of Market Efficiency: A study in foreign exchange markets. *Faculty of Social Sciences, Waseda University, Japan.* Retrieved online: https://acfr.aut.ac.nz/__data/assets/pdf_file/0006/29859/484224-confYK.pdf

Kosapattarapim, C., Lin, Y., McCrae, M., 2013. Size and power of cointegration tests with non-normal GARCH error distributions. *International Journal of Statistics and Economics,* 10, (1), 65-74. Retrieved online: https://pdfs.semanticscholar.org/8d87/4b1ca6e0b921e98f08a85c8836ab73c5e26a.pdf

Kumar, A.S., Kamaiah, B., 2016. Efficiency, non-linearity and chaos: evidence from BRICS foreign exchange markets. *Theoretical and Applied Economics, 23,* (601), 103-118. Retrieved online: https://www.researchgate.net/publication/322931467_Efficiency_non-linearity_and_chaos_evidences_from_BRICS_foreign_exchange_markets

Levich, R.M., 1978. Further Results on the Efficiency of Markets for Foreign Exchange. Retrieved online: http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.373.128

Levich, R.M., 1989. Is the Foreign Exchange Market Efficient? *Oxford Economic Review of Economic Policy.* Retrieved online: https://www.jstor.org/stable/23605772

Love & Payne, 2006. Macroeconomic news, order flows and exchange rates. Retrieved online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=991890

Lo, A.W., Mackinlay, A.C., 1988. Stock prices do not follow random walks: Evidence from a simple specification test. *Review of Financial Studies,* vol 1., p.41-66

Madura, J., 2013. International Financial Management 12th Edition. Canada: Cengage Learning.

Maggio, M., Kermani, A., Palmer, C., 2016. How Quantitative Easing Works: Evidence on the Refinancing Channel. *Harvard Business School.* Retrieved online: https://www.hbs.edu/behavioral-finance-and-financial-stability/Documents/2016-08%20How%20QE%20Works.pdf

Mahajan, A., Mehta, D., 1984. Strong Form Efficiency of the Foreign Exchange Rate Market and Bank Positions. *The Journal of Financial Research.* Retrieved online: http://0-web.b.ebscohost.com.innopac.wits.ac.za/ehost/pdfviewer/pdfviewer?vid=3&sid=d0f03a83-ff1e-4e77-b1f5-76756240edb6%40pdc-v-sessmgr02

Makovsky´, P., 2014. Modern approaches to efficient market hypothesis of Forex- the central European Case. ELSVIER. Retrieved online: https://www.researchgate.net/publication/268822950_Modern_Approaches_to_Efficient_Market_Hypothesis_of_FOREX_-_The_Central_European_Case/download

Matebejana, G., Motlaleng, G., Juana, J., 2017. Foreign Exchange Market Efficiency In Botswana. Review of Economic and Business Studies. Retrieved online : https://www.researchgate.net/publication/318734021_Foreign_Exchange_Market_Efficiency_In_Botswana

Mbululu, D., Auret, C.J., Chiliba, L., 2013. Do exchange rates follow random walks? A variance ratio test of the Zambian foreign-exchange market. *Southern African Business Review, 17* (2), 45-66. Retrieved online: https://www.ajol.info/index.php/sabr/article/viewFile/110915/100677

Merton, R., 1981. On market timing and investment performance. I. An equilibrium theory of value for market forecasts. Journal of Business 54, 363-406

Mukherjee, S., 2018. The Efficiency of Foreign Exchange Markets in Emerging Economies: Evidence in BRICS Countries (Master's Dissertation). Retrieved From: http://jultika.oulu.fi/files/nbnfioulu-201811283117.pdf

Nielsen, H.B., 2005. Non-Stationary Time Series and Unit Root Tests. Retrieved online: http://web.econ.ku.dk/metrics/Econometrics2_05_II/Slides/08_unitroottests_2pp.pdf

Neely, C.J., Weller, P.A., 2011. Technical Analysis in the Foreign Exchange Market. *Research Division Federal Reserve Bank of St. Louis.* Retrieved online: https://files.stlouisfed.org/files/htdocs/wp/2011/2011-001.pdf

Noman, A.M., Ahmed, M.U., 2008. Efficiency of the foreign exchange markets in South Asian Countries. *AIUB Business and Economics Working Paper Series, 18.* Retrieved online: https://core.ac.uk/download/pdf/6851567.pdf

Ojah, K., Karemera, D., 1999. Random Walks and Market Efficiency Tests of Latin American Emerging Equity Markets: A Revisit. *The Financial Review.* Retrieved online: https://www.academia.edu/26192339/Random_Walks_and_Market_Efficiency_Tests_of_Latin_American_Emerging_Equity_Markets_A_Revisit

Pantelis, A., Zehtabchis, M., 2008. Testing for unit roots in the presence of structural change IRAN-GREECE CPI case. *Lund University School of Economics and Management.* Retrieved online: http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=1338330&fileOId=1646631

Pedroni, P. (1997). Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Indiana University.* Retrieved Online: https://pdfs.semanticscholar.org/a9a2/81b43484bf108681755ccd4eb51da292d76c.pdf?_ga=2.174840292.791338404.1557133272-685427669.1557133272

Pukthuanthong-Le, K., Thomas, R. L., 2008. Weak-Form Efficiency in Currency Markets. Financial Analysts Journal, Vol. 64, No. 3, pp. 31-32, 35-52. Retrieved online: https://www.jstor.org/stable/40390214

Pilbeam, K., Olmo, J., 2011. The forward discount puzzle and market efficiency. Annals of Finance 7, 119-135.

Rashid, A., 2006. Do exchange rates follow random walks? An application of variance ratio test. *Pakistan Economic and Social Review.* vol. XLIV, No.1. pp.57-79. Retrieved online: https://www.jstor.org/stable/25825284

Reuters, 2018. The life and times of ECB quantitative easing, 2015-2018. *Reuters.* Retrieved online: https://www.reuters.com/article/us-eurozone-ecb-qe/the-life-and-times-of-ecb-quantitative-easing-2015-18-idUSKBN1OB1SM

Sarno, L., Taylor, P.M., 2002. Purchasing Power Parity and the Real Exchange Rate. *International Monetary Fund.* Retrieved online: https://www.imf.org/External/Pubs/FT/staffp/2002/01/pdf/sarno.pdf

Sasikumar, A., 2011. Testing for weak form market efficiency in Indian Foreign Exchange Market. *Munich Personal RePEc Archive.* Retrieved Online: https://mpra.ub.uni-muenchen.de/37071/1/MPRA_paper_37071.pdf

Sether, L., Wasendorf, R.R., 2009. *Personal Investor Series: Forex Trading*. USA, Iowa: W&A Publishing

Summers, H.L., 1986. Does the Stock Market Rationally Reflect Fundamental Values? *The Journal of Finance.* Retrieved online: https://www.jstor.org/stable/2328487

Wang, G., Xie, C., 2011. Multi-Scale Approximate Entropy Analysis of Foreign Exchange Markets Efficiency. *Systems Engineering Procedia, 3* (2012) 201-208. Retrieved online:

https://reader.elsevier.com/reader/sd/pii/S2211381911001196?token=F0C03792B027DDFE4F7896E32528D9135856232CBD60B283619FE01E796DCE36BA0209B437D40BF3644312B2EA8DBBCC

Wickremasinghe, B.G., 2004. Efficiency of Foreign Exchange Markets: A Developing Country Perspective. *Department of Econometrics & Business Statistics.* Retrieved online: file:///C:/Users/Darion/Downloads/SSRN-id609285.pdf

Wright, J. 2000. Alternative variance ratio tests using ranks and signs. *Journal of Business and Economics Statistics,* vol.18, p.1-9

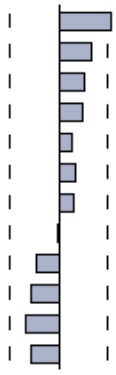
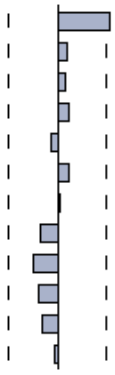
Yang, Y.H., Shao, Y.H., Shao, H.L., Stanley, H.E., 2019. Revisiting the weak-form efficiency of the EUR/CHF exchange rate market: Evidence from episodes of different Swiss Frank regimes. *ELSVIER PHYSICA A: Statistical Mechanics and its Applications*. vol. 523. pp.734-746 Retrieved online: https://doi.org/10.1016/j.physa.2019.02.056

Yaya, S.O., Saka, L., Akanbi, B.O., 2019. Assessing Market Efficiency and Volatility of Exchange Rates in South Africa and United Kingdom: Analysis Using Hurst Exponent. *The Journal of Developing Areas*. Vol. 53, No.1, Retrieved online: https://www.questia.com/library/journal/1P4-2094385244/assessing-market-efficiency-and-volatility-of-exchange

16. Appendix

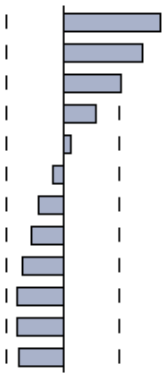
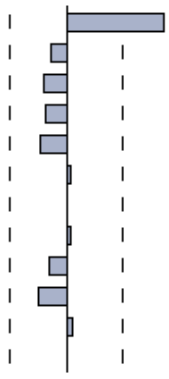
Appendix A1. ZAR/USD Prior QE1

Date: 08/22/19 Time: 16:28
Sample: 2007M01 2008M10
Included observations: 22

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.466	0.466	5.4492	0.020
		2	0.284	0.086	7.5756	0.023
		3	0.223	0.080	8.9527	0.030
		4	0.218	0.094	10.346	0.035
		5	0.109	-0.061	10.714	0.057
		6	0.144	0.096	11.401	0.077
		7	0.135	0.026	12.038	0.099
		8	-0.012	-0.154	12.043	0.149
		9	-0.189	-0.220	13.499	0.141
		10	-0.253	-0.166	16.326	0.091
		11	-0.288	-0.139	20.294	0.041
		12	-0.249	-0.019	23.567	0.023

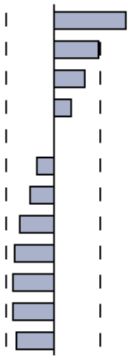
Appendix A2. ZAR/USD During QE 1

Date: 08/21/19 Time: 12:03
Sample: 2008M11 2010M03
Included observations: 17

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.851	0.851	14.622	0.000
		2	0.690	-0.126	24.863	0.000
		3	0.501	-0.196	30.645	0.000
		4	0.295	-0.187	32.801	0.000
		5	0.069	-0.232	32.928	0.000
		6	-0.096	0.043	33.198	0.000
		7	-0.217	0.006	34.724	0.000
		8	-0.284	0.034	37.629	0.000
		9	-0.345	-0.154	42.425	0.000
		10	-0.403	-0.241	49.929	0.000
		11	-0.402	0.057	58.644	0.000
		12	-0.380	0.003	67.981	0.000

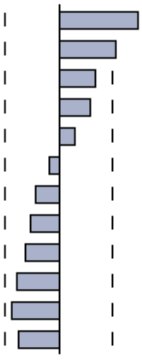
Appendix A3. INR/USD Prior QE1

Date: 08/21/19 Time: 12:36
Sample: 2007M01 2008M10
Included observations: 22

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.672	0.672	11.343	0.001
		2	0.411	-0.073	15.809	0.000
		3	0.280	0.059	17.985	0.000
		4	0.164	-0.057	18.772	0.001
		5	0.016	-0.134	18.780	0.002
		6	-0.150	-0.176	19.522	0.003
		7	-0.212	-0.014	21.106	0.004
		8	-0.308	-0.197	24.692	0.002
		9	-0.358	-0.054	29.886	0.000
		10	-0.367	-0.084	35.827	0.000
		11	-0.365	-0.095	42.222	0.000
		12	-0.337	-0.074	48.211	0.000

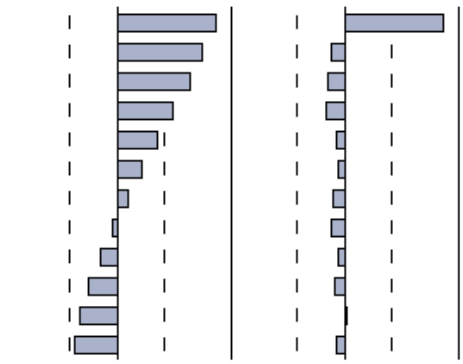
Appendix A4. INR/USD During QE1

Date: 08/21/19 Time: 12:36
Sample: 2008M11 2010M03
Included observations: 17

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.736	0.736	10.932	0.001
		2	0.517	-0.053	16.697	0.000
		3	0.334	-0.062	19.266	0.000
		4	0.286	0.168	21.298	0.000
		5	0.142	-0.237	21.840	0.001
		6	-0.083	-0.311	22.043	0.001
		7	-0.215	0.045	23.541	0.001
		8	-0.266	-0.050	26.082	0.001
		9	-0.300	-0.146	29.728	0.000
		10	-0.392	-0.111	36.819	0.000
		11	-0.431	-0.012	46.808	0.000
		12	-0.369	0.021	55.617	0.000

Appendix A5. CNY/USD Prior QE 1

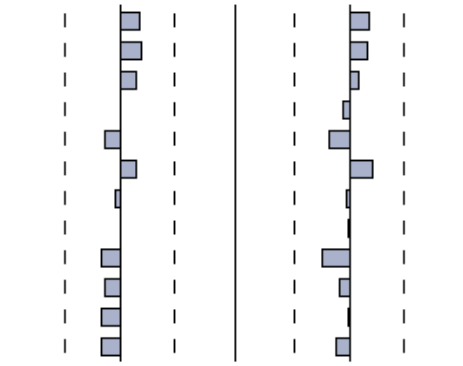
Date: 08/21/19 Time: 12:52
Sample: 2007M01 2008M10
Included observations: 22



	AC	PAC	Q-Stat	Prob
1	0.899	0.899	20.323	0.000
2	0.786	-0.116	36.634	0.000
3	0.657	-0.143	48.643	0.000
4	0.510	-0.169	56.287	0.000
5	0.367	-0.069	60.469	0.000
6	0.231	-0.055	62.228	0.000
7	0.097	-0.099	62.557	0.000
8	-0.035	-0.116	62.602	0.000
9	-0.149	-0.052	63.509	0.000
10	-0.256	-0.093	66.384	0.000
11	-0.330	0.026	71.615	0.000
12	-0.392	-0.081	79.732	0.000

Appendix A6. CNY/USD During QE1

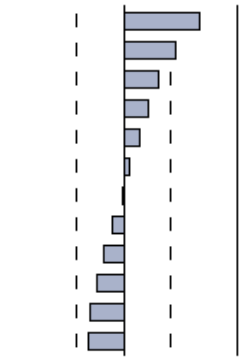
Date: 08/21/19 Time: 12:52
Sample: 2008M11 2010M03
Included observations: 17



	AC	PAC	Q-Stat	Prob
1	0.183	0.183	0.6730	0.412
2	0.193	0.165	1.4750	0.478
3	0.141	0.087	1.9346	0.586
4	0.008	-0.060	1.9363	0.747
5	-0.134	-0.177	2.4173	0.789
6	0.152	0.211	3.0977	0.796
7	-0.035	-0.030	3.1380	0.872
8	0.002	-0.016	3.1382	0.925
9	-0.166	-0.238	4.2532	0.894
10	-0.130	-0.090	5.0314	0.889
11	-0.167	-0.002	6.5338	0.835
12	-0.169	-0.108	8.3823	0.755

Appendix A7. BRL/USD Prior QE1

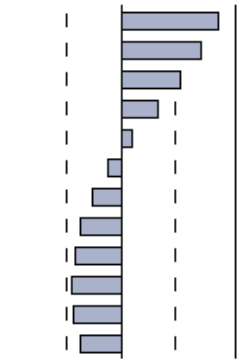
Date: 08/21/19 Time: 13:05
Sample: 2007M01 2008M10
Included observations: 22



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.700	0.700	12.331	0.000
		2	0.470	-0.039	18.170	0.000
		3	0.326	0.022	21.124	0.000
		4	0.230	0.006	22.677	0.000
		5	0.146	-0.032	23.337	0.000
		6	0.061	-0.058	23.460	0.001
		7	-0.002	-0.031	23.460	0.001
		8	-0.103	-0.140	23.857	0.002
		9	-0.176	-0.063	25.110	0.003
		10	-0.240	-0.096	27.636	0.002
		11	-0.299	-0.107	31.934	0.001
		12	-0.316	-0.036	37.199	0.000

Appendix A8. BRL/USD During QE1

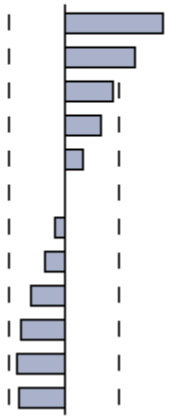
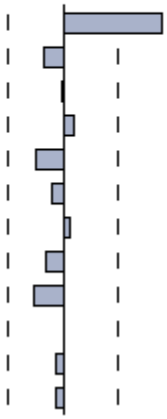
Date: 08/21/19 Time: 13:07
Sample: 2008M11 2010M03
Included observations: 17



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.891	0.891	16.020	0.000
		2	0.731	-0.305	27.516	0.000
		3	0.548	-0.160	34.438	0.000
		4	0.330	-0.277	37.144	0.000
		5	0.096	-0.212	37.391	0.000
		6	-0.113	-0.048	37.764	0.000
		7	-0.255	0.140	39.860	0.000
		8	-0.364	-0.090	44.616	0.000
		9	-0.424	0.015	51.868	0.000
		10	-0.451	-0.166	61.260	0.000
		11	-0.438	-0.027	71.591	0.000
		12	-0.375	0.109	80.652	0.000

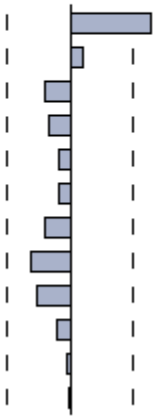
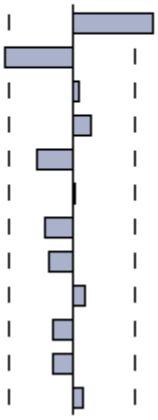
Appendix A9. RUB/USD Prior QE1

Date: 08/21/19 Time: 13:18
Sample: 2007M01 2008M10
Included observations: 22

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.787	0.787	15.554	0.000
		2	0.561	-0.151	23.864	0.000
		3	0.383	-0.016	27.944	0.000
		4	0.288	0.084	30.376	0.000
		5	0.145	-0.221	31.031	0.000
		6	0.002	-0.083	31.031	0.000
		7	-0.078	0.050	31.243	0.000
		8	-0.142	-0.127	32.000	0.000
		9	-0.258	-0.224	34.710	0.000
		10	-0.340	0.014	39.793	0.000
		11	-0.369	-0.057	46.322	0.000
		12	-0.353	-0.052	52.888	0.000

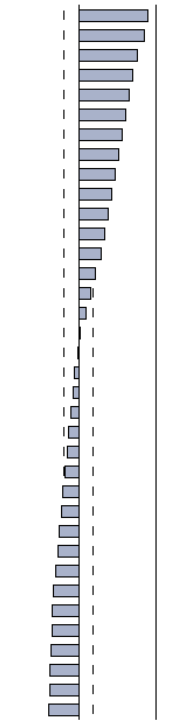
Appendix A10. RUB/USD Post QE 1

Date: 08/21/19 Time: 13:19
Sample: 2008M11 2010M03
Included observations: 17

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.642	0.642	8.3135	0.004
		2	0.107	-0.519	8.5578	0.014
		3	-0.204	0.060	9.5145	0.023
		4	-0.164	0.149	10.186	0.037
		5	-0.098	-0.286	10.444	0.064
		6	-0.095	0.031	10.711	0.098
		7	-0.202	-0.221	12.027	0.100
		8	-0.299	-0.175	15.227	0.055
		9	-0.256	0.100	17.875	0.037
		10	-0.106	-0.146	18.391	0.049
		11	-0.020	-0.153	18.412	0.073
		12	-0.005	0.085	18.413	0.104

Appendix B1. BRL/EUR Prior QE1

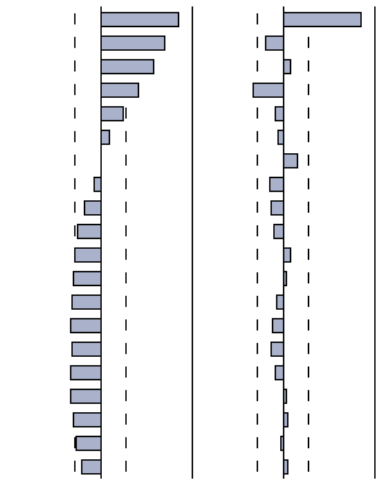
Date: 08/21/19 Time: 16:36
Sample: 2007M01 2015M02
Included observations: 98



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.940	0.940	89.221	0.000
		2	0.880	-0.025	168.30	0.000
		3	0.803	-0.185	234.77	0.000
		4	0.730	-0.007	290.27	0.000
		5	0.678	0.173	338.76	0.000
		6	0.641	0.087	382.50	0.000
		7	0.597	-0.148	420.86	0.000
		8	0.547	-0.122	453.41	0.000
		9	0.498	0.056	480.72	0.000
		10	0.445	0.012	502.82	0.000
		11	0.404	0.026	521.23	0.000
		12	0.353	-0.175	535.45	0.000
		13	0.298	-0.117	545.67	0.000
		14	0.236	-0.024	552.19	0.000
		15	0.164	-0.094	555.35	0.000
		16	0.094	-0.058	556.40	0.000
		17	0.028	-0.062	556.50	0.000
		18	-0.016	0.122	556.53	0.000
		19	-0.053	0.021	556.88	0.000
		20	-0.076	0.013	557.60	0.000
		21	-0.103	-0.075	558.95	0.000
		22	-0.123	0.064	560.91	0.000
		23	-0.151	-0.014	563.88	0.000
		24	-0.181	-0.082	568.22	0.000
		25	-0.207	-0.028	573.97	0.000
		26	-0.231	0.028	581.23	0.000
		27	-0.258	-0.058	590.41	0.000
		28	-0.285	-0.076	601.79	0.000
		29	-0.307	-0.019	615.21	0.000
		30	-0.331	-0.020	631.02	0.000
		31	-0.350	-0.048	648.89	0.000
		32	-0.357	0.006	667.84	0.000
		33	-0.368	-0.098	688.28	0.000
		34	-0.379	-0.066	710.23	0.000
		35	-0.386	0.058	733.39	0.000
		36	-0.396	-0.026	758.22	0.000

Appendix B2. BRL/EUR During QE1

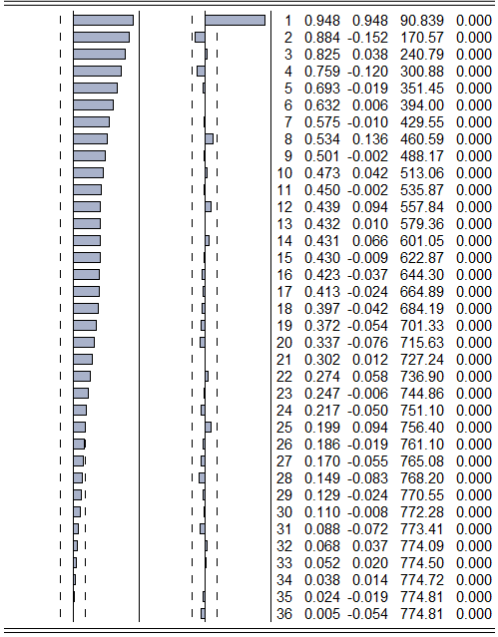
Date: 08/21/19 Time: 16:36
Sample: 2015M03 2018M12
Included observations: 46



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.879	0.879	37.915	0.000
		2	0.726	-0.205	64.377	0.000
		3	0.607	0.083	83.297	0.000
		4	0.439	-0.343	93.447	0.000
		5	0.257	-0.089	96.992	0.000
		6	0.106	-0.061	97.614	0.000
		7	0.013	0.169	97.623	0.000
		8	-0.081	-0.153	98.003	0.000
		9	-0.188	-0.127	100.12	0.000
		10	-0.263	-0.101	104.38	0.000
		11	-0.293	0.089	109.79	0.000
		12	-0.305	0.033	115.81	0.000
		13	-0.324	-0.081	122.85	0.000
		14	-0.329	-0.107	130.30	0.000
		15	-0.321	-0.124	137.65	0.000
		16	-0.331	-0.089	145.71	0.000
		17	-0.335	0.049	154.23	0.000
		18	-0.310	0.051	161.80	0.000
		19	-0.273	-0.032	167.88	0.000
		20	-0.215	0.054	171.81	0.000

Appendix B3. CNY/EUR Prior QE 1

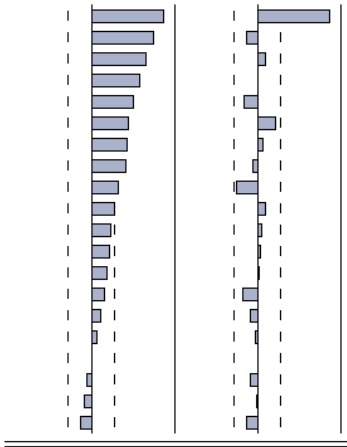
Date: 08/22/19 Time: 10:02
Sample: 2007M01 2015M02
Included observations: 98



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.948	0.948	90.839	0.000
		2	0.884	-0.152	170.57	0.000
		3	0.825	0.038	240.79	0.000
		4	0.759	-0.120	300.88	0.000
		5	0.693	-0.019	351.45	0.000
		6	0.632	0.006	394.00	0.000
		7	0.575	-0.010	429.55	0.000
		8	0.534	0.136	460.59	0.000
		9	0.501	-0.002	488.17	0.000
		10	0.473	0.042	513.06	0.000
		11	0.450	-0.002	535.87	0.000
		12	0.439	0.094	557.84	0.000
		13	0.432	0.010	579.36	0.000
		14	0.431	0.066	601.05	0.000
		15	0.430	-0.009	622.87	0.000
		16	0.423	-0.037	644.30	0.000
		17	0.413	-0.024	664.89	0.000
		18	0.397	-0.042	684.19	0.000
		19	0.372	-0.054	701.33	0.000
		20	0.337	-0.076	715.63	0.000
		21	0.302	0.012	727.24	0.000
		22	0.274	0.058	736.90	0.000
		23	0.247	-0.006	744.86	0.000
		24	0.217	-0.050	751.10	0.000
		25	0.199	0.094	756.40	0.000
		26	0.186	-0.019	761.10	0.000
		27	0.170	-0.055	765.08	0.000
		28	0.149	-0.083	768.20	0.000
		29	0.129	-0.024	770.55	0.000
		30	0.110	-0.008	772.28	0.000
		31	0.088	-0.072	773.41	0.000
		32	0.068	0.037	774.09	0.000
		33	0.052	0.020	774.50	0.000
		34	0.038	0.014	774.72	0.000
		35	0.024	-0.019	774.81	0.000
		36	0.005	-0.054	774.81	0.000

Appendix B4. CNY/EUR During QE1

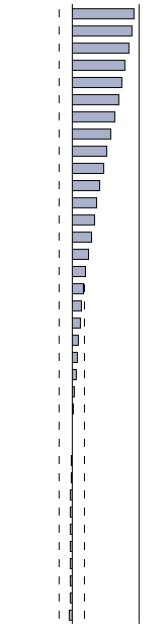
Date: 08/22/19 Time: 10:03
Sample: 2015M03 2018M12
Included observations: 46



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.895	0.895	39.266	0.000
		2	0.775	-0.126	69.413	0.000
		3	0.687	0.096	93.646	0.000
		4	0.614	0.004	113.50	0.000
		5	0.517	-0.165	127.87	0.000
		6	0.466	0.226	139.88	0.000
		7	0.452	0.074	151.44	0.000
		8	0.428	-0.053	162.06	0.000
		9	0.341	-0.264	169.00	0.000
		10	0.280	0.094	173.80	0.000
		11	0.250	0.063	177.73	0.000
		12	0.224	0.033	180.98	0.000
		13	0.190	0.029	183.40	0.000
		14	0.158	-0.181	185.11	0.000
		15	0.120	-0.086	186.13	0.000
		16	0.067	-0.027	186.47	0.000
		17	0.003	0.014	186.47	0.000
		18	-0.057	-0.090	186.72	0.000
		19	-0.095	-0.009	187.46	0.000
		20	-0.138	-0.129	189.07	0.000

Appendix B5. INR/EUR Prior QE1

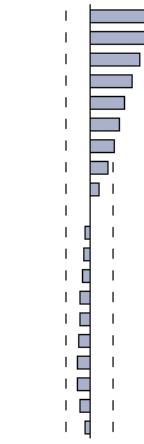
Date: 08/22/19 Time: 10:11
Sample: 2007M01 2015M02
Included observations: 98



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.971	0.971	95.226	0.000
		2	0.933	-0.162	184.14	0.000
		3	0.888	-0.140	265.44	0.000
		4	0.835	-0.116	338.19	0.000
		5	0.780	-0.047	402.26	0.000
		6	0.726	0.042	458.47	0.000
		7	0.668	-0.130	506.46	0.000
		8	0.608	-0.023	546.76	0.000
		9	0.548	-0.051	579.85	0.000
		10	0.489	0.006	606.52	0.000
		11	0.437	0.082	628.02	0.000
		12	0.391	0.040	645.41	0.000
		13	0.345	-0.071	659.11	0.000
		14	0.302	-0.025	669.74	0.000
		15	0.261	-0.006	677.80	0.000
		16	0.220	-0.050	683.59	0.000
		17	0.181	-0.020	687.55	0.000
		18	0.151	0.119	690.35	0.000
		19	0.127	0.030	692.33	0.000
		20	0.104	-0.038	693.70	0.000
		21	0.085	-0.017	694.62	0.000
		22	0.067	-0.013	695.19	0.000
		23	0.042	-0.146	695.43	0.000
		24	0.027	0.155	695.53	0.000
		25	0.015	0.014	695.56	0.000
		26	0.003	-0.072	695.56	0.000
		27	-0.003	0.094	695.56	0.000
		28	-0.009	-0.077	695.57	0.000
		29	-0.018	0.010	695.62	0.000
		30	-0.025	-0.036	695.71	0.000
		31	-0.029	0.084	695.83	0.000
		32	-0.030	0.037	695.96	0.000
		33	-0.030	-0.103	696.09	0.000
		34	-0.031	-0.020	696.24	0.000
		35	-0.031	0.047	696.39	0.000
		36	-0.038	-0.137	696.62	0.000

Appendix B6. INR/EUR During QE 1

Date: 08/22/19 Time: 10:12
Sample: 2015M03 2018M12
Included observations: 46



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.878	0.878	37.828	0.000
		2	0.735	-0.157	64.941	0.000
		3	0.621	0.055	84.756	0.000
		4	0.526	-0.010	99.304	0.000
		5	0.429	-0.072	109.20	0.000
		6	0.361	0.082	116.40	0.000
		7	0.311	-0.002	121.87	0.000
		8	0.234	-0.152	125.05	0.000
		9	0.108	-0.240	125.74	0.000
		10	0.000	0.000	125.74	0.000
		11	-0.056	0.091	125.94	0.000
		12	-0.069	0.122	126.25	0.000
		13	-0.091	-0.092	126.80	0.000
		14	-0.113	-0.063	127.68	0.000
		15	-0.120	0.028	128.70	0.000
		16	-0.132	0.009	129.99	0.000
		17	-0.148	0.052	131.65	0.000
		18	-0.146	-0.008	133.33	0.000
		19	-0.110	0.024	134.33	0.000
		20	-0.066	0.007	134.70	0.000

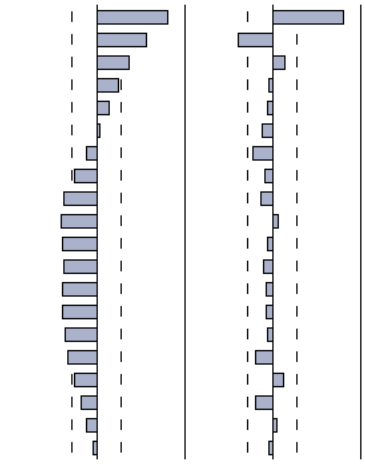
Appendix B7. RUB/EUR Prior QE 1

Date: 08/22/19 Time: 10:24
Sample: 2007M01 2015M02
Included observations: 98

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.858	0.858	74.423	0.000
		2	0.664	-0.274	119.50	0.000
		3	0.491	0.000	144.41	0.000
		4	0.401	0.188	161.19	0.000
		5	0.350	-0.019	174.07	0.000
		6	0.319	0.030	184.92	0.000
		7	0.298	0.059	194.51	0.000
		8	0.289	0.044	203.58	0.000
		9	0.281	0.018	212.24	0.000
		10	0.258	-0.031	219.68	0.000
		11	0.217	-0.040	224.96	0.000
		12	0.164	-0.030	228.02	0.000
		13	0.120	0.002	229.68	0.000
		14	0.090	-0.007	230.63	0.000
		15	0.068	-0.030	231.17	0.000
		16	0.052	0.008	231.49	0.000
		17	0.039	-0.015	231.67	0.000
		18	0.024	-0.024	231.75	0.000
		19	0.002	-0.037	231.75	0.000
		20	-0.016	0.011	231.78	0.000
		21	-0.039	-0.042	231.98	0.000
		22	-0.056	0.002	232.38	0.000
		23	-0.075	-0.037	233.10	0.000
		24	-0.080	0.025	233.96	0.000
		25	-0.078	0.003	234.78	0.000
		26	-0.067	0.011	235.40	0.000
		27	-0.060	-0.006	235.89	0.000
		28	-0.055	0.007	236.31	0.000
		29	-0.052	0.011	236.69	0.000
		30	-0.047	0.009	237.01	0.000
		31	-0.041	0.005	237.26	0.000
		32	-0.041	-0.015	237.50	0.000
		33	-0.049	-0.029	237.87	0.000
		34	-0.047	0.052	238.20	0.000
		35	-0.034	0.005	238.39	0.000
		36	-0.015	0.009	238.42	0.000

Appendix B8. RUB/EUR During QE 1

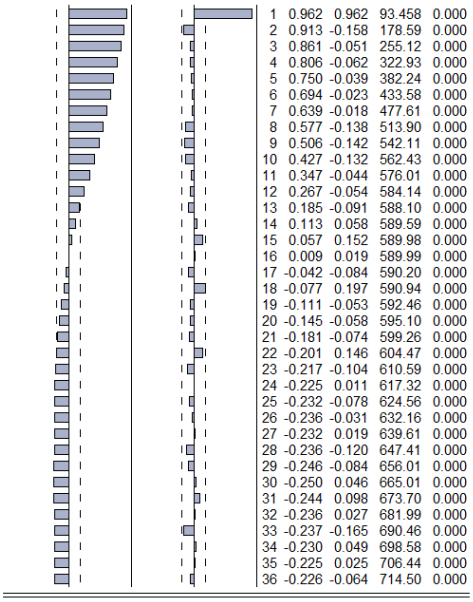
Date: 08/22/19 Time: 10:25
Sample: 2015M03 2018M12
Included observations: 46



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.840	0.840	34.642	0.000
		2	0.589	-0.400	52.023	0.000
		3	0.393	0.147	59.939	0.000
		4	0.260	-0.049	63.482	0.000
		5	0.153	-0.060	64.746	0.000
		6	0.040	-0.122	64.833	0.000
		7	-0.110	-0.223	65.523	0.000
		8	-0.260	-0.082	69.442	0.000
		9	-0.378	-0.136	77.947	0.000
		10	-0.419	0.066	88.692	0.000
		11	-0.404	-0.062	99.005	0.000
		12	-0.390	-0.104	108.90	0.000
		13	-0.393	-0.077	119.26	0.000
		14	-0.393	-0.081	129.94	0.000
		15	-0.370	-0.052	139.68	0.000
		16	-0.340	-0.190	148.18	0.000
		17	-0.262	0.130	153.41	0.000
		18	-0.182	-0.197	156.01	0.000
		19	-0.111	0.059	157.01	0.000
		20	-0.041	-0.034	157.16	0.000

Appendix B9. ZAR/EUR Prior QE

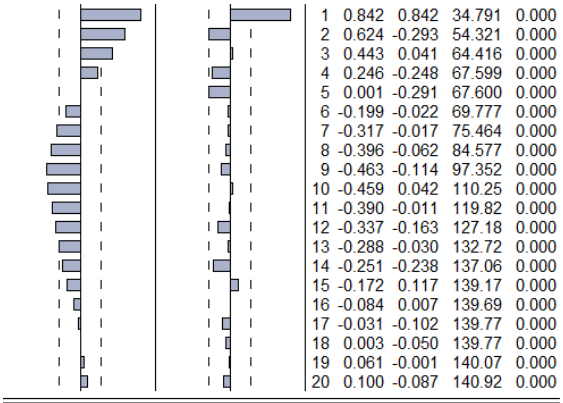
Date: 08/22/19 Time: 10:30
Sample: 2007M01 2015M02
Included observations: 98



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.962	0.962	93.458	0.000
		2	0.913	-0.158	178.59	0.000
		3	0.861	-0.051	255.12	0.000
		4	0.806	-0.062	322.93	0.000
		5	0.750	-0.039	382.24	0.000
		6	0.694	-0.023	433.58	0.000
		7	0.639	-0.018	477.61	0.000
		8	0.577	-0.138	513.90	0.000
		9	0.506	-0.142	542.11	0.000
		10	0.427	-0.132	562.43	0.000
		11	0.347	-0.044	576.01	0.000
		12	0.267	-0.054	584.14	0.000
		13	0.185	-0.091	588.10	0.000
		14	0.113	0.058	589.59	0.000
		15	0.057	0.152	589.98	0.000
		16	0.009	0.019	589.99	0.000
		17	-0.042	-0.084	590.20	0.000
		18	-0.077	0.197	590.94	0.000
		19	-0.111	-0.053	592.46	0.000
		20	-0.145	-0.058	595.10	0.000
		21	-0.181	-0.074	599.26	0.000
		22	-0.201	0.146	604.47	0.000
		23	-0.217	-0.104	610.59	0.000
		24	-0.225	0.011	617.32	0.000
		25	-0.232	-0.078	624.56	0.000
		26	-0.236	-0.031	632.16	0.000
		27	-0.232	0.019	639.61	0.000
		28	-0.236	-0.120	647.41	0.000
		29	-0.246	-0.084	656.01	0.000
		30	-0.250	0.046	665.01	0.000
		31	-0.244	0.098	673.70	0.000
		32	-0.236	0.027	681.99	0.000
		33	-0.237	-0.165	690.46	0.000
		34	-0.230	0.049	698.58	0.000
		35	-0.225	0.025	706.44	0.000
		36	-0.226	-0.064	714.50	0.000

Appendix B10. ZAR/EUR During QE 1

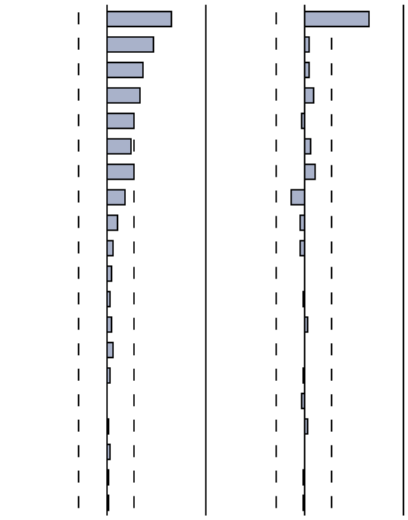
Date: 08/22/19 Time: 10:31
Sample: 2015M03 2018M12
Included observations: 46



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.842	0.842	34.791	0.000
		2	0.624	-0.293	54.321	0.000
		3	0.443	0.041	64.416	0.000
		4	0.246	-0.248	67.599	0.000
		5	0.001	-0.291	67.600	0.000
		6	-0.199	-0.022	69.777	0.000
		7	-0.317	-0.017	75.464	0.000
		8	-0.396	-0.062	84.577	0.000
		9	-0.463	-0.114	97.352	0.000
		10	-0.459	0.042	110.25	0.000
		11	-0.390	-0.011	119.82	0.000
		12	-0.337	-0.163	127.18	0.000
		13	-0.288	-0.030	132.72	0.000
		14	-0.251	-0.238	137.06	0.000
		15	-0.172	0.117	139.17	0.000
		16	-0.084	0.007	139.69	0.000
		17	-0.031	-0.102	139.77	0.000
		18	0.003	-0.050	139.77	0.000
		19	0.061	-0.001	140.07	0.000
		20	0.100	-0.087	140.92	0.000

Appendix C1. ZAR/USD Autocorrelation Test at Levels (2005.01-2008.10)

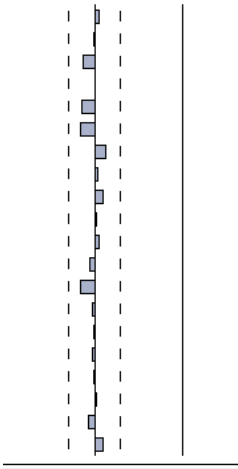
Sample: 2005M01 2008M10
Included observations: 46



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.676	0.676	22.401	0.000
		2	0.491	0.063	34.492	0.000
		3	0.388	0.064	42.226	0.000
		4	0.352	0.100	48.749	0.000
		5	0.283	-0.024	53.048	0.000
		6	0.265	0.075	56.910	0.000
		7	0.290	0.114	61.667	0.000
		8	0.200	-0.138	63.986	0.000
		9	0.122	-0.043	64.876	0.000
		10	0.067	-0.039	65.148	0.000
		11	0.062	0.015	65.392	0.000
		12	0.041	-0.003	65.501	0.000
		13	0.056	0.045	65.708	0.000
		14	0.068	0.011	66.025	0.000
		15	0.047	-0.016	66.180	0.000
		16	0.012	-0.021	66.191	0.000
		17	0.020	0.046	66.221	0.000
		18	0.034	0.011	66.312	0.000
		19	0.032	-0.001	66.393	0.000
		20	0.032	-0.003	66.482	0.000

Appendix C2. ZAR/USD Autocorrelation Test at First Difference (2005.01-2008.10)

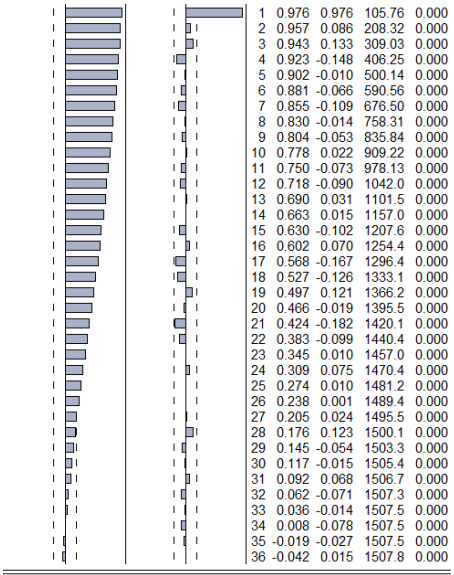
Sample: 2005M01 2008M10
Included observations: 45



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.065	0.065	0.2024	0.653
		2	-0.009	-0.013	0.2065	0.902
		3	-0.133	-0.132	1.1008	0.777
		4	0.014	0.032	1.1110	0.893
		5	-0.145	-0.153	2.2213	0.818
		6	-0.170	-0.174	3.7843	0.706
		7	0.137	0.172	4.8244	0.681
		8	0.038	-0.030	4.9083	0.767
		9	0.100	0.066	5.4961	0.789
		10	0.022	0.054	5.5248	0.853
		11	0.049	-0.018	5.6763	0.894
		12	-0.064	-0.032	5.9379	0.919
		13	-0.156	-0.103	7.5547	0.871
		14	-0.022	-0.001	7.5871	0.910
		15	-0.006	0.015	7.5893	0.939
		16	-0.022	-0.072	7.6246	0.959
		17	-0.004	0.002	7.6261	0.974
		18	0.019	-0.047	7.6557	0.983
		19	-0.072	-0.138	8.0827	0.986
		20	0.096	0.173	8.8678	0.984

Appendix C3. ZAR/USD Autocorrelation Test at Levels (2008.11-2017.10)

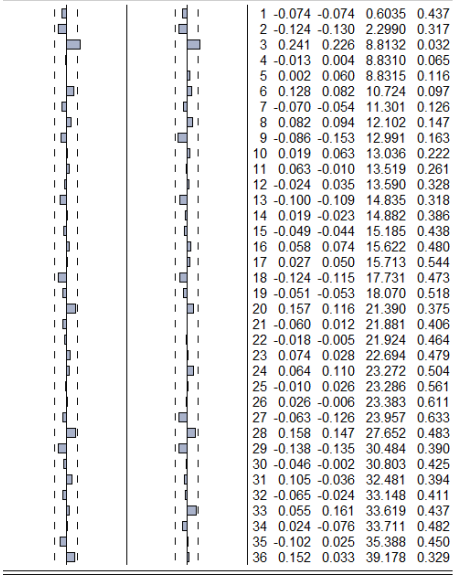
Sample: 2008M11 2017M10
Included observations: 108



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.976	0.976	105.76	0.000
		2	0.957	0.086	208.32	0.000
		3	0.943	0.133	309.03	0.000
		4	0.923	-0.148	406.25	0.000
		5	0.902	-0.010	500.14	0.000
		6	0.881	-0.066	590.56	0.000
		7	0.855	-0.109	676.50	0.000
		8	0.830	-0.014	758.31	0.000
		9	0.804	-0.053	835.84	0.000
		10	0.778	0.022	909.22	0.000
		11	0.750	-0.073	978.13	0.000
		12	0.718	-0.090	1042.0	0.000
		13	0.690	0.031	1101.5	0.000
		14	0.663	0.015	1157.0	0.000
		15	0.630	-0.102	1207.6	0.000
		16	0.602	0.070	1254.4	0.000
		17	0.568	-0.167	1296.4	0.000
		18	0.527	-0.126	1333.1	0.000
		19	0.497	0.121	1366.2	0.000
		20	0.466	-0.019	1395.5	0.000
		21	0.424	-0.182	1420.1	0.000
		22	0.383	-0.099	1440.4	0.000
		23	0.345	0.010	1457.0	0.000
		24	0.309	0.075	1470.4	0.000
		25	0.274	0.010	1481.2	0.000
		26	0.238	0.001	1489.4	0.000
		27	0.205	0.024	1495.5	0.000
		28	0.176	0.123	1500.1	0.000
		29	0.145	-0.054	1503.3	0.000
		30	0.117	-0.015	1505.4	0.000
		31	0.092	0.068	1506.7	0.000
		32	0.062	-0.071	1507.3	0.000
		33	0.036	-0.014	1507.5	0.000
		34	0.008	-0.078	1507.5	0.000
		35	-0.019	-0.027	1507.5	0.000
		36	-0.042	0.015	1507.8	0.000

Appendix C4. ZAR/USD Autocorrelation Test at First Difference (2008.11-2017.10)

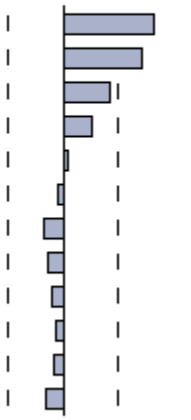
Sample: 2008M11 2017M10
Included observations: 107



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.074	-0.074	0.6035	0.437
		2	-0.124	-0.130	2.2990	0.317
		3	0.241	0.226	8.8132	0.032
		4	-0.013	0.004	8.8310	0.065
		5	0.002	0.060	8.8315	0.116
		6	0.128	0.082	10.724	0.097
		7	-0.070	-0.054	11.301	0.126
		8	0.082	0.094	12.102	0.147
		9	-0.086	-0.153	12.991	0.163
		10	0.019	0.063	13.036	0.222
		11	0.063	-0.010	13.519	0.261
		12	-0.024	0.035	13.590	0.328
		13	-0.100	-0.109	14.835	0.318
		14	0.019	-0.023	14.882	0.386
		15	-0.049	-0.044	15.185	0.438
		16	0.058	0.074	15.622	0.480
		17	0.027	0.050	15.713	0.544
		18	-0.124	-0.115	17.731	0.473
		19	-0.051	-0.053	18.070	0.518
		20	0.157	0.116	21.390	0.375
		21	-0.060	0.012	21.881	0.406
		22	-0.018	-0.005	21.924	0.464
		23	0.074	0.028	22.694	0.479
		24	0.064	0.110	23.272	0.504
		25	-0.010	0.026	23.286	0.561
		26	0.026	-0.006	23.383	0.611
		27	-0.063	-0.126	23.957	0.633
		28	0.158	0.147	27.652	0.483
		29	-0.138	-0.135	30.484	0.390
		30	-0.046	-0.002	30.803	0.425
		31	0.105	-0.036	32.481	0.394
		32	-0.065	-0.024	33.148	0.411
		33	0.055	0.161	33.619	0.437
		34	0.024	-0.076	33.711	0.482
		35	-0.102	0.025	35.388	0.450
		36	0.152	0.033	39.178	0.329

Appendix C5. ZAR/USD Autocorrelation Test at Levels (2017.11-2019.08)

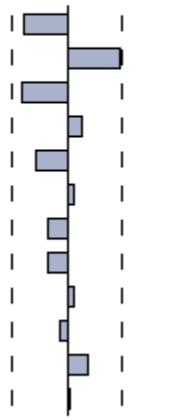
Sample: 2017M11 2019M08
Included observations: 22



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.709	0.709	12.624	0.000
		2	0.630	0.256	23.092	0.000
		3	0.366	-0.318	26.807	0.000
		4	0.224	-0.095	28.281	0.000
		5	0.042	-0.062	28.337	0.000
		6	-0.048	-0.017	28.413	0.000
		7	-0.142	-0.040	29.119	0.000
		8	-0.113	0.122	29.601	0.000
		9	-0.091	0.073	29.936	0.000
		10	-0.064	-0.097	30.114	0.001
		11	-0.079	-0.137	30.412	0.001
		12	-0.125	-0.144	31.234	0.002

Appendix C6. ZAR/USD Autocorrelation Test at First Difference (2017.11-2019.08)

Sample: 2017M11 2019M08
Included observations: 21



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.332	-0.332	2.6652	0.103
		2	0.419	0.347	7.1337	0.028
		3	-0.354	-0.188	10.489	0.015
		4	0.109	-0.180	10.824	0.029
		5	-0.244	-0.089	12.618	0.027
		6	0.054	-0.061	12.712	0.048
		7	-0.144	-0.099	13.427	0.062
		8	-0.156	-0.360	14.327	0.074
		9	0.052	-0.024	14.437	0.108
		10	-0.051	0.053	14.552	0.149
		11	0.156	-0.040	15.731	0.151
		12	0.031	0.008	15.784	0.201

Appendix C7. ZAR/USD UIP Test (2005.01-2008.10)

Dependent Variable: DFW_SPOT
Method: Least Squares
Date: 09/19/19 Time: 13:21
Sample: 2005M01 2008M10
Included observations: 46

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000918	0.000351	2.618769	0.0121
DYIELD	0.002006	5.44E-05	36.89287	0.0000

R-squared	0.968685	Mean dependent var	0.012381
Adjusted R-squared	0.967973	S.D. dependent var	0.006167
S.E. of regression	0.001104	Akaike info criterion	-10.73776
Sum squared resid	5.36E-05	Schwarz criterion	-10.65826
Log likelihood	248.9686	Hannan-Quinn criter.	-10.70798
F-statistic	1361.084	Durbin-Watson stat	1.410464
Prob(F-statistic)	0.000000		

Appendix C8. ZAR/USD UIP Test (2008.11-2017.10)

Dependent Variable: DLFW_SPOT
Method: Least Squares
Date: 09/19/19 Time: 16:51
Sample: 2008M11 2017M10
Included observations: 108

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.003136	0.000613	5.115844	0.0000
DYIELD	0.001943	9.59E-05	20.26250	0.0000

R-squared	0.794800	Mean dependent var	0.015385
Adjusted R-squared	0.792864	S.D. dependent var	0.002319
S.E. of regression	0.001056	Akaike info criterion	-10.85097
Sum squared resid	0.000118	Schwarz criterion	-10.80130
Log likelihood	587.9523	Hannan-Quinn criter.	-10.83083
F-statistic	410.5688	Durbin-Watson stat	0.579357
Prob(F-statistic)	0.000000		

Appendix C9. ZAR/USD UIP Test (2017.11-2019.08)

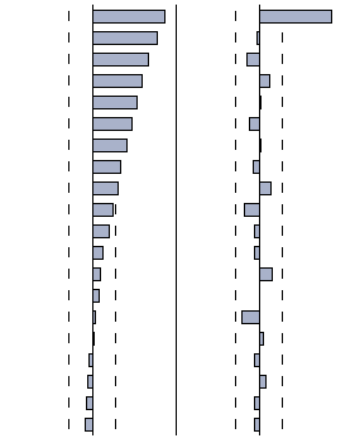
Dependent Variable: LOG(ZAR_USD__T_3_)-LOG(ZAR_USD)
Method: Least Squares
Date: 09/20/19 Time: 10:17
Sample (adjusted): 2017M11 2019M08
Included observations: 22 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.006246	0.001783	3.502010	0.0022
SA_3M-US_3M	0.001202	0.000379	3.170929	0.0048

R-squared	0.334549	Mean dependent var	0.011874
Adjusted R-squared	0.301276	S.D. dependent var	0.000977
S.E. of regression	0.000816	Akaike info criterion	-11.29689
Sum squared resid	1.33E-05	Schwarz criterion	-11.19771
Log likelihood	126.2658	Hannan-Quinn criter.	-11.27353
F-statistic	10.05479	Durbin-Watson stat	1.069334
Prob(F-statistic)	0.004804		

Appendix D1. BRL/USD Autocorrelation Test at Levels (2005.01-2008.10)

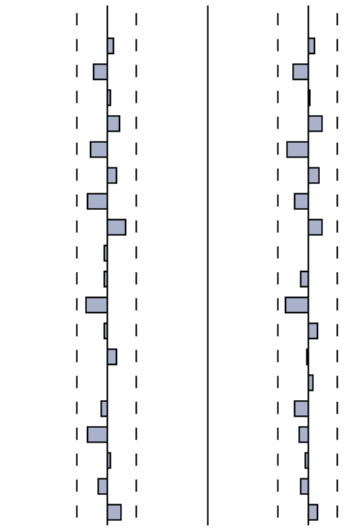
Date: 09/22/19 Time: 14:01
Sample: 2005M01 2008M10
Included observations: 46



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.902	0.902	39.956	0.000
		2	0.810	-0.021	72.914	0.000
		3	0.699	-0.154	98.019	0.000
		4	0.625	0.130	118.53	0.000
		5	0.561	0.031	135.47	0.000
		6	0.491	-0.113	148.79	0.000
		7	0.430	0.022	159.27	0.000
		8	0.358	-0.075	166.70	0.000
		9	0.325	0.147	173.00	0.000
		10	0.263	-0.175	177.24	0.000
		11	0.209	-0.058	179.98	0.000
		12	0.136	-0.059	181.18	0.000
		13	0.105	0.170	181.92	0.000
		14	0.086	0.006	182.43	0.000
		15	0.047	-0.209	182.59	0.000
		16	0.018	0.056	182.61	0.000
		17	-0.039	-0.064	182.73	0.000
		18	-0.055	0.086	182.97	0.000
		19	-0.079	-0.055	183.47	0.000
		20	-0.090	-0.057	184.15	0.000

Appendix D2. BRL/USD Autocorrelation Test at First Difference (2005.01-2008.10)

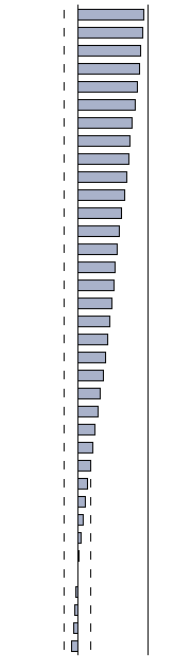
Date: 09/22/19 Time: 14:03
Sample: 2005M01 2008M10
Included observations: 45



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.014	0.014	0.0092	0.923
		2	0.081	0.081	0.3300	0.848
		3	-0.137	-0.140	1.2750	0.735
		4	0.033	0.032	1.3312	0.856
		5	0.128	0.153	2.1986	0.821
		6	-0.166	-0.208	3.6924	0.718
		7	0.100	0.108	4.2462	0.751
		8	-0.189	-0.138	6.2859	0.615
		9	0.199	0.151	8.6193	0.473
		10	-0.021	0.006	8.6472	0.566
		11	-0.026	-0.072	8.6908	0.650
		12	-0.214	-0.225	11.627	0.476
		13	-0.024	0.099	11.665	0.555
		14	0.102	-0.002	12.369	0.577
		15	0.011	0.055	12.378	0.650
		16	-0.060	-0.139	12.645	0.699
		17	-0.196	-0.090	15.539	0.557
		18	0.034	-0.032	15.630	0.618
		19	-0.089	-0.068	16.276	0.639
		20	0.148	0.103	18.120	0.580

Appendix D3. BRL/USD Autocorrelation Test at Levels (2008.11-2017.10)

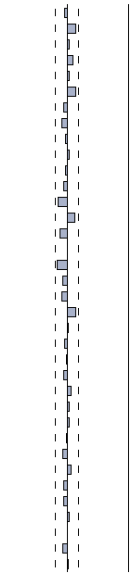
Date: 09/22/19 Time: 14:04
Sample: 2008M11 2017M10
Included observations: 108



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.978	0.978	106.27	0.000
		2	0.960	0.057	209.48	0.000
		3	0.937	-0.101	308.76	0.000
		4	0.913	-0.045	403.98	0.000
		5	0.883	-0.156	493.91	0.000
		6	0.853	-0.042	578.57	0.000
		7	0.818	-0.093	657.28	0.000
		8	0.786	0.030	730.59	0.000
		9	0.755	0.077	799.04	0.000
		10	0.725	-0.002	862.75	0.000
		11	0.691	-0.094	921.24	0.000
		12	0.655	-0.099	974.37	0.000
		13	0.624	0.070	1023.0	0.000
		14	0.595	0.070	1067.8	0.000
		15	0.563	-0.082	1108.3	0.000
		16	0.534	0.032	1145.0	0.000
		17	0.504	-0.015	1178.2	0.000
		18	0.472	-0.103	1207.6	0.000
		19	0.445	0.073	1234.0	0.000
		20	0.418	-0.021	1257.6	0.000
		21	0.379	-0.301	1277.2	0.000
		22	0.339	-0.085	1293.1	0.000
		23	0.301	0.013	1305.8	0.000
		24	0.264	0.028	1315.6	0.000
		25	0.228	0.100	1323.1	0.000
		26	0.189	-0.102	1328.2	0.000
		27	0.153	0.059	1331.6	0.000
		28	0.119	0.025	1333.7	0.000
		29	0.089	0.024	1334.9	0.000
		30	0.060	-0.030	1335.5	0.000
		31	0.032	-0.007	1335.6	0.000
		32	0.002	-0.010	1335.6	0.000
		33	-0.021	0.043	1335.7	0.000
		34	-0.043	-0.028	1336.0	0.000
		35	-0.064	-0.003	1336.7	0.000
		36	-0.082	0.034	1337.8	0.000

Appendix D4. BRL/USD Autocorrelation Test at First Difference (2008.11-2017.10)

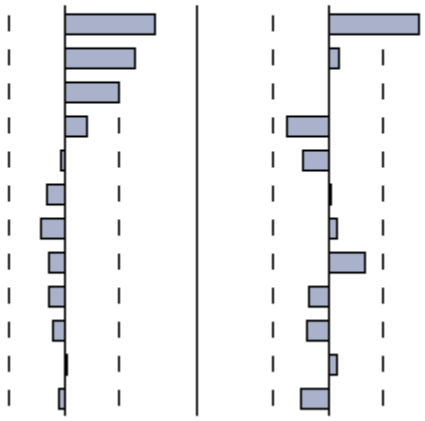
Date: 09/22/19 Time: 14:09
Sample: 2008M11 2017M10
Included observations: 107



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.043	-0.043	0.2075	0.649
		2	0.144	0.143	2.5247	0.283
		3	0.044	0.057	2.7402	0.433
		4	0.103	0.089	3.9416	0.414
		5	0.043	0.039	4.1577	0.527
		6	0.144	0.124	6.5674	0.363
		7	-0.050	-0.060	6.8636	0.443
		8	-0.082	-0.143	7.6645	0.467
		9	-0.028	-0.051	7.7548	0.559
		10	0.046	0.053	8.0056	0.628
		11	-0.017	0.008	8.0410	0.710
		12	-0.051	-0.057	8.3565	0.757
		13	-0.145	-0.132	10.978	0.613
		14	0.131	0.170	13.133	0.516
		15	-0.107	-0.058	14.595	0.481
		16	0.014	-0.049	14.619	0.553
		17	-0.166	-0.154	18.193	0.377
		18	-0.079	-0.070	19.020	0.391
		19	-0.088	-0.018	20.049	0.392
		20	0.150	0.143	23.065	0.286
		21	0.026	0.107	23.155	0.336
		22	-0.045	-0.018	23.436	0.377
		23	-0.009	0.009	23.446	0.435
		24	-0.064	-0.115	24.028	0.460
		25	0.075	0.008	24.819	0.473
		26	0.042	-0.002	25.075	0.515
		27	0.038	0.074	25.285	0.558
		28	-0.000	0.027	25.285	0.612
		29	-0.073	-0.071	26.091	0.621
		30	0.067	0.002	26.775	0.635
		31	-0.056	-0.067	27.253	0.659
		32	-0.058	-0.102	27.772	0.681
		33	0.045	0.107	28.085	0.710
		34	0.004	0.002	28.087	0.752
		35	-0.067	-0.085	28.820	0.760
		36	0.021	-0.006	28.890	0.794

Appendix D5. BRL/USD Autocorrelation Test at Levels (2017.11-2019.08)

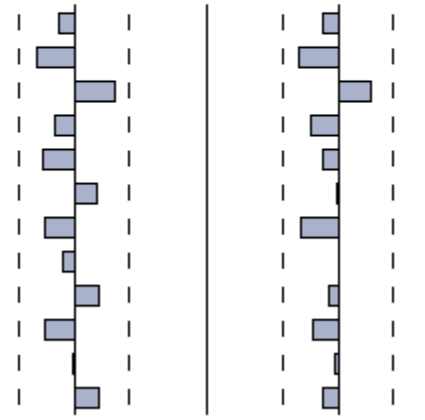
Date: 09/22/19 Time: 14:08
Sample: 2017M11 2019M08
Included observations: 22



	AC	PAC	Q-Stat	Prob
1	0.720	0.720	13.051	0.000
2	0.560	0.084	21.320	0.000
3	0.430	0.000	26.462	0.000
4	0.178	-0.320	27.394	0.000
5	-0.030	-0.194	27.422	0.000
6	-0.124	0.032	27.931	0.000
7	-0.187	0.082	29.157	0.000
8	-0.112	0.282	29.629	0.000
9	-0.112	-0.141	30.135	0.000
10	-0.097	-0.159	30.548	0.001
11	0.022	0.070	30.570	0.001
12	-0.041	-0.212	30.660	0.002

Appendix D6. BRL/USD Autocorrelation Test at First Difference (2017.11-2019.08)

Date: 09/22/19 Time: 14:05
Sample: 2017M11 2019M08
Included observations: 21



	AC	PAC	Q-Stat	Prob
1	-0.117	-0.117	0.3329	0.564
2	-0.291	-0.309	2.4820	0.289
3	0.319	0.267	5.2102	0.157
4	-0.148	-0.207	5.8307	0.212
5	-0.246	-0.122	7.6590	0.176
6	0.187	-0.012	8.7795	0.186
7	-0.228	-0.294	10.569	0.159
8	-0.083	0.012	10.827	0.212
9	0.196	-0.079	12.379	0.193
10	-0.227	-0.202	14.641	0.146
11	-0.013	-0.028	14.649	0.199
12	0.204	-0.108	16.892	0.154

Appendix D7. BRL/USD UIP Testing (2006.02-2008.10)

Dependent Variable: LOG(BRL_USD__T_3_)-LOG(BRL_USD)
Method: Least Squares
Date: 09/22/19 Time: 15:41
Sample (adjusted): 2006M02 2008M10
Included observations: 33 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.014075	0.001321	10.65136	0.0000
(BRL3M_YIELD)-(US3M_YIELD)	0.001072	0.000334	3.207715	0.0031

R-squared	0.249203	Mean dependent var	0.016973
Adjusted R-squared	0.224983	S.D. dependent var	0.006292
S.E. of regression	0.005539	Akaike info criterion	-7.495343
Sum squared resid	0.000951	Schwarz criterion	-7.404646
Log likelihood	125.6732	Hannan-Quinn criter.	-7.464826
F-statistic	10.28943	Durbin-Watson stat	0.750180
Prob(F-statistic)	0.003102		

Appendix D8. BRL/USD UIP Testing (2008.11-2011.08)

Dependent Variable: LOG(FWBRL_USD01)-LOG(BRL_USD)
Method: Least Squares
Date: 09/22/19 Time: 17:57
Sample: 2008M11 2011M08
Included observations: 34

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.004595	0.007505	-0.612222	0.5447
BRL3MYIELD-US3MYIELD	0.002426	0.000706	3.435700	0.0017

R-squared	0.269474	Mean dependent var	0.020934
Adjusted R-squared	0.246645	S.D. dependent var	0.007074
S.E. of regression	0.006140	Akaike info criterion	-7.290843
Sum squared resid	0.001207	Schwarz criterion	-7.201057
Log likelihood	125.9443	Hannan-Quinn criter.	-7.260224
F-statistic	11.80404	Durbin-Watson stat	0.456231
Prob(F-statistic)	0.001656		

Appendix D9. BRL/USD UIP Testing (2016.11-2017.10)

Dependent Variable: LOG(BRL_USD_T_3)-LOG(BRL_USD)
Method: Least Squares
Date: 09/22/19 Time: 18:15
Sample: 2016M03 2017M10
Included observations: 20

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000145	0.001557	0.093245	0.9267
BRL_3M_YIELD-US_3M_YIELD	0.001974	0.000134	14.76184	0.0000

R-squared	0.923700	Mean dependent var	0.022492
Adjusted R-squared	0.919461	S.D. dependent var	0.005749
S.E. of regression	0.001632	Akaike info criterion	-9.903812
Sum squared resid	4.79E-05	Schwarz criterion	-9.804239
Log likelihood	101.0381	Hannan-Quinn criter.	-9.884375
F-statistic	217.9119	Durbin-Watson stat	1.225957
Prob(F-statistic)	0.000000		

Appendix D10. BRL/USD UIP Testing (2017.11-2019.08)

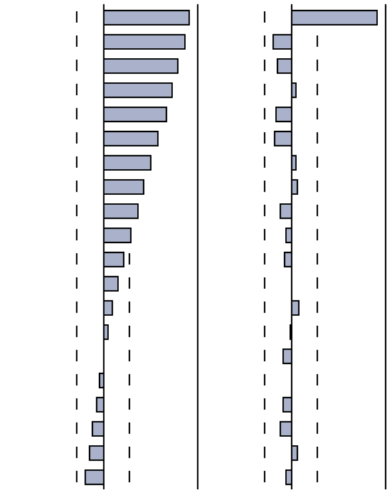
Dependent Variable: LOG(BRL_USD_T_3)-LOG(BRL_USD)
Method: Least Squares
Date: 09/22/19 Time: 16:22
Sample (adjusted): 2017M11 2019M08
Included observations: 22 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000853	0.001684	-0.506553	0.6180
BRL_3M_YIELD-US_3M_Y	0.002010	0.000379	5.297755	0.0000

R-squared	0.583907	Mean dependent var	0.008005
Adjusted R-squared	0.563103	S.D. dependent var	0.001398
S.E. of regression	0.000924	Akaike info criterion	-11.04858
Sum squared resid	1.71E-05	Schwarz criterion	-10.94939
Log likelihood	123.5343	Hannan-Quinn criter.	-11.02521
F-statistic	28.06620	Durbin-Watson stat	0.562665
Prob(F-statistic)	0.000035		

Appendix E1. RUB/USD Autocorrelation Test at Levels (2005.01-2008.10)

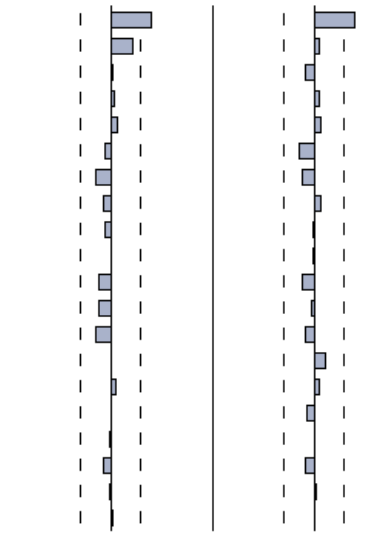
Date: 09/23/19 Time: 07:53
Sample: 2005M01 2008M10
Included observations: 46



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.956	0.956	44.849	0.000
		2	0.898	-0.189	85.299	0.000
		3	0.828	-0.143	120.51	0.000
		4	0.763	0.059	151.14	0.000
		5	0.689	-0.160	176.72	0.000
		6	0.603	-0.177	196.82	0.000
		7	0.521	0.056	212.16	0.000
		8	0.448	0.077	223.84	0.000
		9	0.377	-0.112	232.35	0.000
		10	0.306	-0.052	238.07	0.000
		11	0.229	-0.069	241.38	0.000
		12	0.160	0.000	243.04	0.000
		13	0.106	0.089	243.79	0.000
		14	0.059	-0.001	244.03	0.000
		15	0.011	-0.090	244.04	0.000
		16	-0.033	0.007	244.12	0.000
		17	-0.077	-0.089	244.57	0.000
		18	-0.119	-0.113	245.68	0.000
		19	-0.154	0.079	247.62	0.000
		20	-0.191	-0.050	250.73	0.000

Appendix E2. RUB/USD Autocorrelation Test at First Difference (2005.01-2008.10)

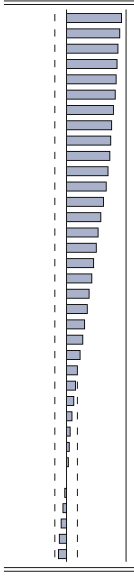
Date: 09/23/19 Time: 07:54
Sample: 2005M01 2008M10
Included observations: 45



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.420	0.420	8.4916	0.004
		2	0.223	0.056	10.941	0.004
		3	0.032	-0.098	10.992	0.012
		4	0.039	0.057	11.070	0.026
		5	0.070	0.067	11.326	0.045
		6	-0.054	-0.144	11.483	0.075
		7	-0.143	-0.115	12.626	0.082
		8	-0.080	0.073	12.996	0.112
		9	-0.052	-0.016	13.153	0.156
		10	0.001	-0.002	13.153	0.215
		11	-0.110	-0.116	13.899	0.239
		12	-0.118	-0.026	14.786	0.253
		13	-0.144	-0.084	16.152	0.241
		14	0.008	0.107	16.157	0.304
		15	0.063	0.055	16.441	0.353
		16	0.002	-0.078	16.441	0.423
		17	-0.007	0.012	16.444	0.493
		18	-0.080	-0.094	16.948	0.527
		19	-0.000	0.025	16.948	0.593
		20	0.029	0.015	17.017	0.652

Appendix E3. RUB/USD Autocorrelation Test at Levels (2008.11-2017.10)

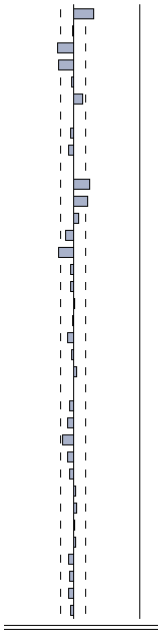
Date: 09/23/19 Time: 07:55
Sample: 2008M11 2017M10
Included observations: 108



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.975	0.975	105.45	0.000
		2	0.941	-0.184	204.60	0.000
		3	0.910	0.075	298.23	0.000
		4	0.885	0.079	387.63	0.000
		5	0.866	0.088	474.15	0.000
		6	0.849	-0.007	558.10	0.000
		7	0.825	-0.126	638.22	0.000
		8	0.802	0.059	714.61	0.000
		9	0.778	-0.040	787.21	0.000
		10	0.755	0.001	856.27	0.000
		11	0.729	-0.101	921.34	0.000
		12	0.692	-0.225	980.62	0.000
		13	0.648	-0.094	1033.2	0.000
		14	0.602	-0.095	1079.0	0.000
		15	0.558	-0.045	1118.8	0.000
		16	0.519	0.010	1153.6	0.000
		17	0.483	-0.050	1184.1	0.000
		18	0.445	-0.023	1210.2	0.000
		19	0.408	0.031	1232.5	0.000
		20	0.370	-0.038	1251.0	0.000
		21	0.327	-0.111	1265.6	0.000
		22	0.285	0.002	1276.8	0.000
		23	0.242	0.007	1285.1	0.000
		24	0.203	0.082	1290.9	0.000
		25	0.168	0.022	1294.9	0.000
		26	0.133	-0.008	1297.5	0.000
		27	0.103	0.103	1299.0	0.000
		28	0.076	0.035	1299.9	0.000
		29	0.055	0.133	1300.4	0.000
		30	0.034	-0.057	1300.5	0.000
		31	0.011	0.017	1300.6	0.000
		32	-0.017	-0.088	1300.6	0.000
		33	-0.050	-0.100	1301.0	0.000
		34	-0.086	-0.106	1302.2	0.000
		35	-0.112	0.110	1304.2	0.000
		36	-0.130	-0.032	1307.0	0.000

Appendix E4. RUB/USD Autocorrelation Test at First Difference (2008.11-2017.10)

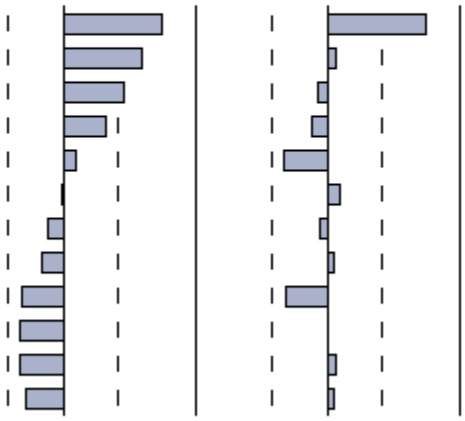
Date: 09/23/19 Time: 07:56
Sample: 2008M11 2017M10
Included observations: 107



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.313	0.313	10.773	0.001
		2	-0.000	-0.109	10.773	0.005
		3	-0.238	-0.229	17.125	0.001
		4	-0.236	-0.104	23.457	0.000
		5	-0.019	0.091	23.499	0.000
		6	0.153	0.098	26.201	0.000
		7	0.001	-0.180	26.201	0.000
		8	-0.033	-0.007	26.329	0.001
		9	-0.080	0.013	27.085	0.001
		10	0.012	0.069	27.104	0.003
		11	0.266	0.239	35.714	0.000
		12	0.230	0.048	42.217	0.000
		13	0.084	0.011	43.100	0.000
		14	-0.116	-0.059	44.797	0.000
		15	-0.234	-0.054	51.726	0.000
		16	-0.040	0.125	51.931	0.000
		17	-0.035	-0.178	52.091	0.000
		18	0.021	-0.029	52.149	0.000
		19	-0.011	-0.029	52.163	0.000
		20	-0.084	-0.051	53.105	0.000
		21	-0.024	0.029	53.183	0.000
		22	0.050	-0.077	53.524	0.000
		23	0.009	-0.074	53.536	0.000
		24	-0.050	-0.138	53.882	0.000
		25	-0.091	-0.002	55.059	0.000
		26	-0.168	-0.058	59.130	0.000
		27	-0.087	-0.103	60.237	0.000
		28	-0.055	-0.051	60.680	0.000
		29	0.039	0.031	60.902	0.000
		30	0.063	0.051	61.495	0.001
		31	0.030	0.022	61.629	0.001
		32	0.042	0.041	61.909	0.001
		33	-0.074	-0.102	62.780	0.001
		34	-0.055	0.013	63.254	0.002
		35	-0.067	0.006	63.987	0.002
		36	-0.042	0.027	64.273	0.003

Appendix E5. RUB/USD Autocorrelation Test at Levels (2017.11-2019.08)

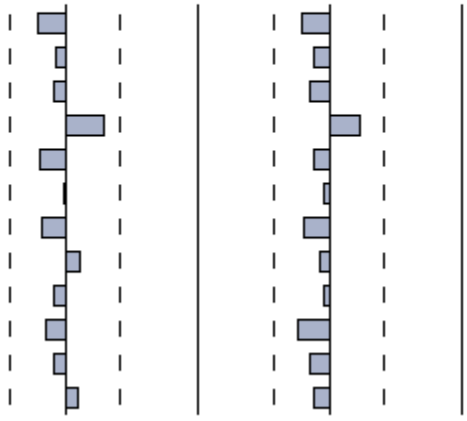
Date: 09/23/19 Time: 07:57
Sample: 2017M11 2019M08
Included observations: 22



	AC	PAC	Q-Stat	Prob
1	0.774	0.774	15.055	0.000
2	0.631	0.079	25.551	0.000
3	0.482	-0.072	32.003	0.000
4	0.330	-0.108	35.196	0.000
5	0.095	-0.330	35.474	0.000
6	-0.004	0.096	35.475	0.000
7	-0.117	-0.065	35.958	0.000
8	-0.167	0.060	37.008	0.000
9	-0.314	-0.315	41.020	0.000
10	-0.335	0.007	45.969	0.000
11	-0.329	0.081	51.164	0.000
12	-0.289	0.050	55.566	0.000

Appendix E6. RUB/USD Autocorrelation Test at First Difference (2017.11-2019.08)

Date: 09/23/19 Time: 07:59
Sample: 2017M11 2019M08
Included observations: 21



	AC	PAC	Q-Stat	Prob
1	-0.211	-0.211	1.0766	0.299
2	-0.072	-0.122	1.2097	0.546
3	-0.098	-0.150	1.4687	0.690
4	0.296	0.248	3.9639	0.411
5	-0.201	-0.118	5.1813	0.394
6	-0.014	-0.038	5.1876	0.520
7	-0.178	-0.199	6.2785	0.508
8	0.113	-0.071	6.7518	0.564
9	-0.082	-0.046	7.0237	0.635
10	-0.153	-0.250	8.0505	0.624
11	-0.093	-0.141	8.4670	0.671
12	0.094	-0.117	8.9443	0.708

Appendix E7. RUB/USD UIP Test (2005.01-2008.10)

Dependent Variable: LOG(RUB_USD__T_3_)-LOG(RUB_USD)
Method: Least Squares
Date: 09/23/19 Time: 11:15
Sample: 2005M01 2008M10
Included observations: 46

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.003512	0.001239	-2.834777	0.0069
RUB_3M_YIELD-US_3M_YIE...	0.003634	0.000345	10.52689	0.0000

R-squared	0.715791	Mean dependent var	0.003031
Adjusted R-squared	0.709331	S.D. dependent var	0.013480
S.E. of regression	0.007268	Akaike info criterion	-6.968241
Sum squared resid	0.002324	Schwarz criterion	-6.888735
Log likelihood	162.2695	Hannan-Quinn criter.	-6.938458
F-statistic	110.8155	Durbin-Watson stat	1.080465
Prob(F-statistic)	0.000000		

Appendix E8. RUB/USD UIP Test (2008.11-2017.10)

Dependent Variable: LOG(RUB_USD__T_3_)-LOG(RUB_USD)
Method: Least Squares
Date: 09/23/19 Time: 11:41
Sample: 2008M11 2017M10
Included observations: 108

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.007021	0.001769	-3.968231	0.0001
RUB_3M_YIELD-US_3M_YIE...	0.003127	0.000173	18.11150	0.0000

R-squared	0.755775	Mean dependent var	0.021652
Adjusted R-squared	0.753471	S.D. dependent var	0.016531
S.E. of regression	0.008208	Akaike info criterion	-6.749121
Sum squared resid	0.007141	Schwarz criterion	-6.699452
Log likelihood	366.4525	Hannan-Quinn criter.	-6.728982
F-statistic	328.0264	Durbin-Watson stat	0.409962
Prob(F-statistic)	0.000000		

Appendix E9. RUB/USD UIP Test (2017.11- 2019.08)

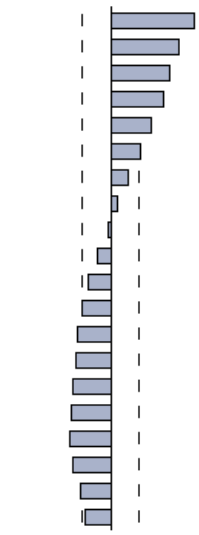
Dependent Variable: LOG(RUB_USD__T_3_)-LOG(RUB_USD)
Method: Least Squares
Date: 09/23/19 Time: 12:43
Sample: 2017M11 2019M08
Included observations: 22

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.003288	0.004412	0.745306	0.4648
RUB_3M_YIELD-US_3M_YIE...	0.001487	0.000822	1.807908	0.0857

R-squared	0.140470	Mean dependent var	0.011248
Adjusted R-squared	0.097494	S.D. dependent var	0.001422
S.E. of regression	0.001351	Akaike info criterion	-10.28938
Sum squared resid	3.65E-05	Schwarz criterion	-10.19019
Log likelihood	115.1832	Hannan-Quinn criter.	-10.26601
F-statistic	3.268532	Durbin-Watson stat	0.155765
Prob(F-statistic)	0.085685		

Appendix F1. INR/USD Autocorrelation Test at Levels (2005.01-2008.10)

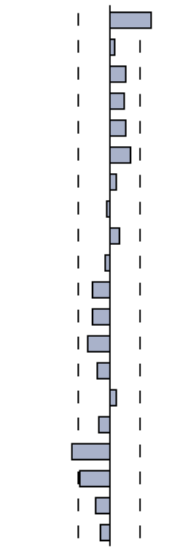
Date: 09/23/19 Time: 15:50
Sample: 2005M01 2008M10
Included observations: 46



	AC	PAC	Q-Stat	Prob
1	0.854	0.854	35.758	0.000
2	0.703	-0.097	60.529	0.000
3	0.613	0.141	79.832	0.000
4	0.533	-0.033	94.790	0.000
5	0.420	-0.142	104.29	0.000
6	0.296	-0.099	109.13	0.000
7	0.188	-0.070	111.13	0.000
8	0.077	-0.122	111.48	0.000
9	-0.026	-0.057	111.52	0.000
10	-0.128	-0.101	112.53	0.000
11	-0.223	-0.087	115.67	0.000
12	-0.295	-0.026	121.32	0.000
13	-0.333	0.021	128.76	0.000
14	-0.352	0.010	137.30	0.000
15	-0.379	-0.065	147.51	0.000
16	-0.403	-0.058	159.46	0.000
17	-0.421	-0.093	172.96	0.000
18	-0.379	0.130	184.31	0.000
19	-0.307	0.073	192.04	0.000
20	-0.270	-0.083	198.23	0.000

Appendix F2. INR/USD Autocorrelation Test at First Difference (2005.01-2008.10)

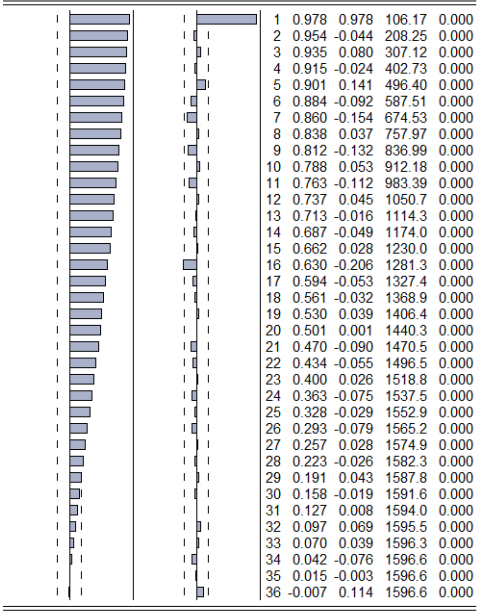
Date: 09/23/19 Time: 17:49
Sample: 2005M01 2008M10
Included observations: 45



	AC	PAC	Q-Stat	Prob
1	0.422	0.422	8.5598	0.003
2	0.060	-0.143	8.7397	0.013
3	0.156	0.233	9.9694	0.019
4	0.154	-0.012	11.195	0.024
5	0.166	0.153	12.646	0.027
6	0.217	0.099	15.199	0.019
7	0.080	-0.080	15.559	0.029
8	-0.018	-0.028	15.578	0.049
9	0.093	0.082	16.089	0.065
10	-0.040	-0.215	16.184	0.094
11	-0.168	-0.082	17.944	0.083
12	-0.165	-0.159	19.696	0.073
13	-0.210	-0.132	22.612	0.047
14	-0.114	0.071	23.501	0.053
15	0.081	0.153	23.963	0.066
16	-0.102	-0.151	24.726	0.075
17	-0.374	-0.192	35.280	0.006
18	-0.293	-0.082	42.008	0.001
19	-0.130	0.049	43.376	0.001
20	-0.095	-0.012	44.145	0.001

Appendix F3. INR/USD Autocorrelation Test at Levels (2008.11-2017.10)

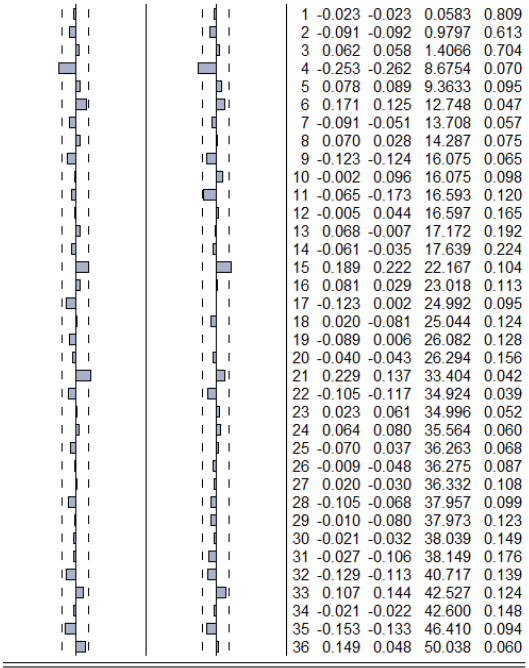
Date: 09/23/19 Time: 17:53
Sample: 2008M11 2017M10
Included observations: 108



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.978	0.978	106.17	0.000
		2	0.954	-0.044	208.25	0.000
		3	0.935	0.080	307.12	0.000
		4	0.915	-0.024	402.73	0.000
		5	0.901	0.141	496.40	0.000
		6	0.884	-0.092	587.51	0.000
		7	0.860	-0.154	674.53	0.000
		8	0.838	0.037	757.97	0.000
		9	0.812	-0.132	836.99	0.000
		10	0.788	0.053	912.18	0.000
		11	0.763	-0.112	983.39	0.000
		12	0.737	0.045	1050.7	0.000
		13	0.713	-0.016	1114.3	0.000
		14	0.687	-0.049	1174.0	0.000
		15	0.662	0.028	1230.0	0.000
		16	0.630	-0.206	1281.3	0.000
		17	0.594	-0.053	1327.4	0.000
		18	0.561	-0.032	1368.9	0.000
		19	0.530	0.039	1406.4	0.000
		20	0.501	0.001	1440.3	0.000
		21	0.470	-0.090	1470.5	0.000
		22	0.434	-0.055	1496.5	0.000
		23	0.400	0.026	1518.8	0.000
		24	0.363	-0.075	1537.5	0.000
		25	0.328	-0.029	1552.9	0.000
		26	0.293	-0.079	1565.2	0.000
		27	0.257	0.028	1574.9	0.000
		28	0.223	-0.026	1582.3	0.000
		29	0.191	0.043	1587.8	0.000
		30	0.158	-0.019	1591.6	0.000
		31	0.127	0.008	1594.0	0.000
		32	0.097	0.069	1595.5	0.000
		33	0.070	0.039	1596.3	0.000
		34	0.042	-0.076	1596.6	0.000
		35	0.015	-0.003	1596.6	0.000
		36	-0.007	0.114	1596.6	0.000

Appendix F4. INR/USD Autocorrelation Test at First Difference (2008.11-2017.10)

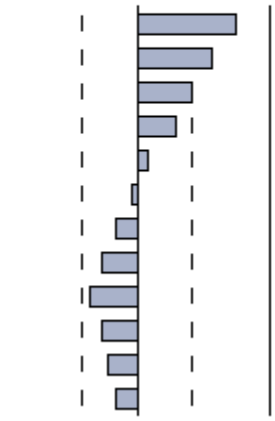
Date: 09/23/19 Time: 17:54
Sample: 2008M11 2017M10
Included observations: 107



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.023	-0.023	0.0583	0.809
		2	-0.091	-0.092	0.9797	0.613
		3	0.062	0.058	1.4066	0.704
		4	-0.253	-0.262	8.6754	0.070
		5	0.078	0.089	9.3633	0.095
		6	0.171	0.125	12.748	0.047
		7	-0.091	-0.051	13.708	0.057
		8	0.070	0.028	14.287	0.075
		9	-0.123	-0.124	16.075	0.065
		10	-0.002	0.096	16.075	0.098
		11	-0.065	-0.173	16.593	0.120
		12	-0.005	0.044	16.597	0.165
		13	0.068	-0.007	17.172	0.192
		14	-0.061	-0.035	17.639	0.224
		15	0.189	0.222	22.167	0.104
		16	0.081	0.029	23.018	0.113
		17	-0.123	0.002	24.992	0.095
		18	0.020	-0.081	25.044	0.124
		19	-0.089	0.006	26.082	0.128
		20	-0.040	-0.043	26.294	0.156
		21	0.229	0.137	33.404	0.042
		22	-0.105	-0.117	34.924	0.039
		23	0.023	0.061	34.996	0.052
		24	0.064	0.080	35.564	0.060
		25	-0.070	0.037	36.263	0.068
		26	-0.009	-0.048	36.275	0.087
		27	0.020	-0.030	36.332	0.108
		28	-0.105	-0.068	37.957	0.099
		29	-0.010	-0.080	37.973	0.123
		30	-0.021	-0.032	38.039	0.149
		31	-0.027	-0.106	38.149	0.176
		32	-0.129	-0.113	40.717	0.139
		33	0.107	0.144	42.527	0.124
		34	-0.021	-0.022	42.600	0.148
		35	-0.153	-0.133	46.410	0.094
		36	0.149	0.048	50.038	0.060

Appendix F5.INR/USD Autocorrelation Test at Levels (2017.11-2019.08)

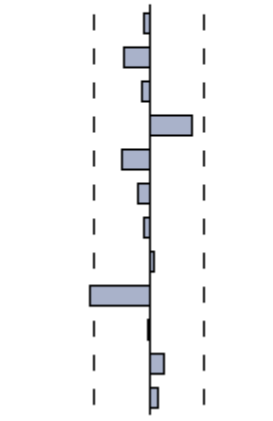
Date: 09/23/19 Time: 17:55
Sample: 2017M11 2019M08
Included observations: 22



	AC	PAC	Q-Stat	Prob
1	0.780	0.780	15.294	0.000
2	0.590	-0.046	24.492	0.000
3	0.433	-0.032	29.704	0.000
4	0.311	-0.013	32.538	0.000
5	0.087	-0.345	32.773	0.000
6	-0.044	0.051	32.836	0.000
7	-0.170	-0.147	33.855	0.000
8	-0.275	-0.114	36.708	0.000
9	-0.373	-0.054	42.372	0.000
10	-0.284	0.289	45.915	0.000
11	-0.238	-0.090	48.622	0.000
12	-0.166	0.091	50.081	0.000

Appendix F6. INR/USD Autocorrelation Test at First Difference (2017.11-2019.08)

Date: 09/23/19 Time: 17:57
Sample: 2017M11 2019M08
Included observations: 21



	AC	PAC	Q-Stat	Prob
1	-0.043	-0.043	0.0452	0.832
2	-0.201	-0.204	1.0765	0.584
3	-0.063	-0.086	1.1843	0.757
4	0.336	0.301	4.3883	0.356
5	-0.209	-0.236	5.7037	0.336
6	-0.083	0.023	5.9259	0.432
7	-0.038	-0.080	5.9746	0.543
8	0.036	-0.129	6.0216	0.645
9	-0.460	-0.430	14.542	0.104
10	-0.007	-0.096	14.544	0.150
11	0.115	-0.060	15.183	0.174
12	0.077	-0.036	15.504	0.215

Appendix F7. INR/USD UIP Test (2005.01-2008.10)

Dependent Variable: LOG(INR_USD__T_3_)-LOG(INR_USD)
Method: Least Squares
Date: 09/23/19 Time: 20:44
Sample: 2005M01 2008M10
Included observations: 46

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.002443	0.001980	1.233931	0.2238
INR_3M_YIELD-US_3M_YIELD	0.001505	0.000538	2.796147	0.0076

R-squared	0.150881	Mean dependent var	0.007137
Adjusted R-squared	0.131583	S.D. dependent var	0.007636
S.E. of regression	0.007116	Akaike info criterion	-7.010335
Sum squared resid	0.002228	Schwarz criterion	-6.930829
Log likelihood	163.2377	Hannan-Quinn criter.	-6.980552
F-statistic	7.818441	Durbin-Watson stat	1.229292
Prob(F-statistic)	0.007639		

Appendix F8. INR/USD UIP Test (2008.11-2017.10)

Dependent Variable: LOG(INR_USD__T_3_)-LOG(INR_USD)
Method: Least Squares
Date: 09/23/19 Time: 20:48
Sample: 2008M11 2017M10
Included observations: 108

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.003290	0.002289	-1.437383	0.1536
INR_3M_YIELD-US_3M_YIELD	0.002673	0.000322	8.288653	0.0000

R-squared	0.393252	Mean dependent var	0.015032
Adjusted R-squared	0.387528	S.D. dependent var	0.007880
S.E. of regression	0.006167	Akaike info criterion	-7.320818
Sum squared resid	0.004032	Schwarz criterion	-7.271149
Log likelihood	397.3242	Hannan-Quinn criter.	-7.300679
F-statistic	68.70176	Durbin-Watson stat	1.068695
Prob(F-statistic)	0.000000		

Appendix F9. INR/USD UIP Test (2017.11-2019.08)

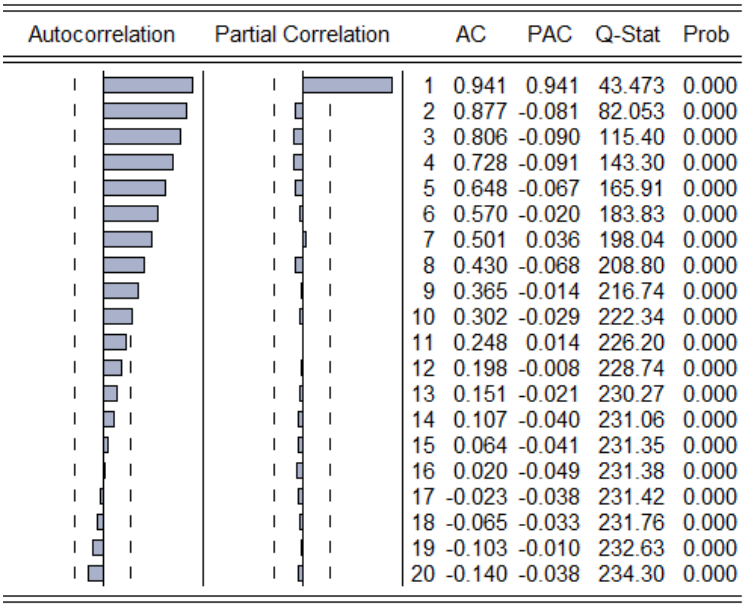
Dependent Variable: LOG(INR_USD__T_3_)-LOG(INR_USD)
Method: Least Squares
Date: 09/23/19 Time: 20:50
Sample (adjusted): 2017M11 2019M08
Included observations: 22 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.022008	0.005645	3.898681	0.0009
INR_3M_YIELD-US_3M_YIELD	-0.002320	0.001298	-1.787882	0.0890

R-squared	0.137802	Mean dependent var	0.011965
Adjusted R-squared	0.094692	S.D. dependent var	0.002758
S.E. of regression	0.002624	Akaike info criterion	-8.961911
Sum squared resid	0.000138	Schwarz criterion	-8.862725
Log likelihood	100.5810	Hannan-Quinn criter.	-8.938546
F-statistic	3.196524	Durbin-Watson stat	1.608241
Prob(F-statistic)	0.088958		

Appendix G1. CNY/USD Autocorrelation Test at Levels (2005.01-2008.10)

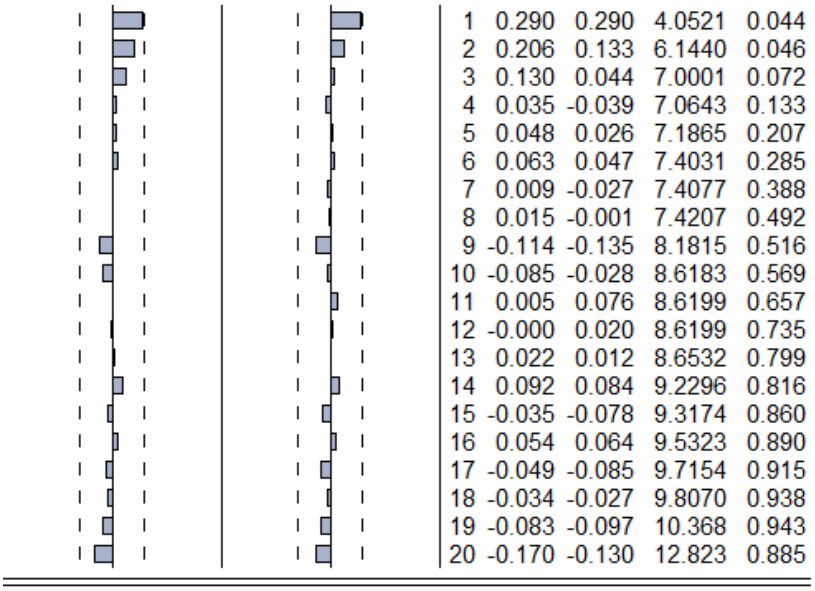
Date: 09/24/19 Time: 10:59
Sample: 2005M01 2008M10
Included observations: 46



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.941	0.941	43.473	0.000
		2	0.877	-0.081	82.053	0.000
		3	0.806	-0.090	115.40	0.000
		4	0.728	-0.091	143.30	0.000
		5	0.648	-0.067	165.91	0.000
		6	0.570	-0.020	183.83	0.000
		7	0.501	0.036	198.04	0.000
		8	0.430	-0.068	208.80	0.000
		9	0.365	-0.014	216.74	0.000
		10	0.302	-0.029	222.34	0.000
		11	0.248	0.014	226.20	0.000
		12	0.198	-0.008	228.74	0.000
		13	0.151	-0.021	230.27	0.000
		14	0.107	-0.040	231.06	0.000
		15	0.064	-0.041	231.35	0.000
		16	0.020	-0.049	231.38	0.000
		17	-0.023	-0.038	231.42	0.000
		18	-0.065	-0.033	231.76	0.000
		19	-0.103	-0.010	232.63	0.000
		20	-0.140	-0.038	234.30	0.000

Appendix G2. CNY/USD Autocorrelation Test at Levels (2005.01-2008.10)

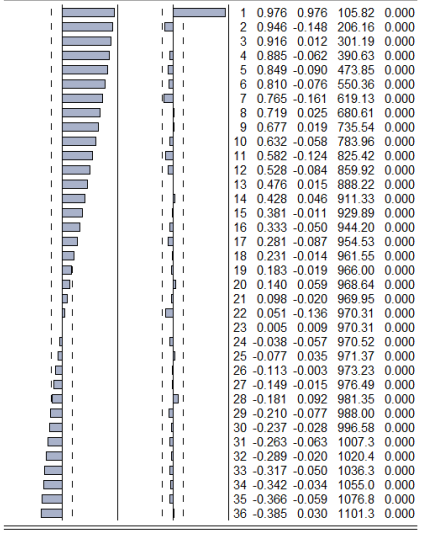
Date: 09/24/19 Time: 10:59
Sample: 2005M01 2008M10
Included observations: 45



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.290	0.290	4.0521	0.044
		2	0.206	0.133	6.1440	0.046
		3	0.130	0.044	7.0001	0.072
		4	0.035	-0.039	7.0643	0.133
		5	0.048	0.026	7.1865	0.207
		6	0.063	0.047	7.4031	0.285
		7	0.009	-0.027	7.4077	0.388
		8	0.015	-0.001	7.4207	0.492
		9	-0.114	-0.135	8.1815	0.516
		10	-0.085	-0.028	8.6183	0.569
		11	0.005	0.076	8.6199	0.657
		12	-0.000	0.020	8.6199	0.735
		13	0.022	0.012	8.6532	0.799
		14	0.092	0.084	9.2296	0.816
		15	-0.035	-0.078	9.3174	0.860
		16	0.054	0.064	9.5323	0.890
		17	-0.049	-0.085	9.7154	0.915
		18	-0.034	-0.027	9.8070	0.938
		19	-0.083	-0.097	10.368	0.943
		20	-0.170	-0.130	12.823	0.885

Appendix G3. CNY/USD Autocorrelation Test at Levels (2008.11-2017.10)

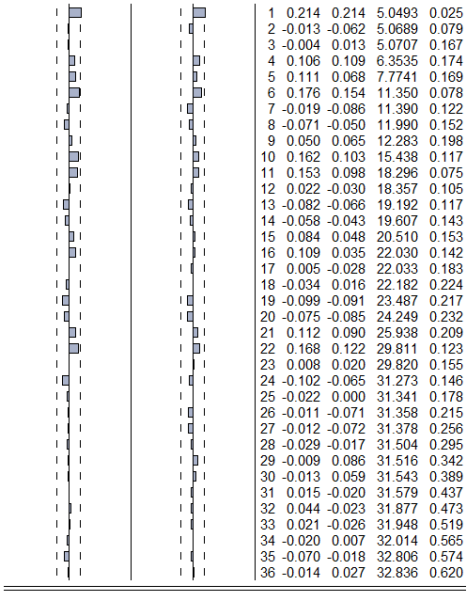
Date: 09/24/19 Time: 11:01
Sample: 2008M11 2017M10
Included observations: 108



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.976	0.976	105.82	0.000
		2	0.946	-0.148	206.16	0.000
		3	0.916	0.012	301.19	0.000
		4	0.885	-0.062	390.63	0.000
		5	0.849	-0.090	473.85	0.000
		6	0.810	-0.076	550.36	0.000
		7	0.765	-0.161	619.13	0.000
		8	0.719	0.025	680.61	0.000
		9	0.677	0.019	735.54	0.000
		10	0.632	-0.058	783.96	0.000
		11	0.582	-0.124	825.42	0.000
		12	0.528	-0.084	859.92	0.000
		13	0.476	0.015	888.22	0.000
		14	0.428	0.046	911.33	0.000
		15	0.381	-0.011	929.89	0.000
		16	0.333	-0.050	944.20	0.000
		17	0.281	-0.087	954.53	0.000
		18	0.231	-0.014	961.55	0.000
		19	0.183	-0.019	966.00	0.000
		20	0.140	0.059	968.64	0.000
		21	0.098	-0.020	969.95	0.000
		22	0.051	-0.136	970.31	0.000
		23	0.005	0.009	970.31	0.000
		24	-0.038	-0.057	970.52	0.000
		25	-0.077	0.035	971.37	0.000
		26	-0.113	-0.003	973.23	0.000
		27	-0.149	-0.015	976.49	0.000
		28	-0.181	0.092	981.35	0.000
		29	-0.210	-0.077	988.00	0.000
		30	-0.237	-0.028	996.58	0.000
		31	-0.263	-0.063	1007.3	0.000
		32	-0.289	-0.020	1020.4	0.000
		33	-0.317	-0.050	1036.3	0.000
		34	-0.342	-0.034	1055.0	0.000
		35	-0.366	-0.059	1076.8	0.000
		36	-0.385	0.030	1101.3	0.000

Appendix G4. CNY/USD Autocorrelation Test at First Difference (2008.11-2017.10)

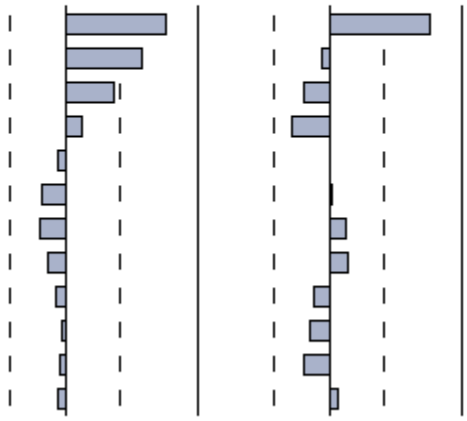
Date: 09/24/19 Time: 11:02
Sample: 2008M11 2017M10
Included observations: 107



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.214	0.214	5.0493	0.025
		2	-0.013	-0.062	5.0689	0.079
		3	-0.004	0.013	5.0707	0.167
		4	0.106	0.109	6.3535	0.174
		5	0.111	0.068	7.7741	0.169
		6	0.176	0.154	11.350	0.078
		7	-0.019	-0.086	11.390	0.122
		8	-0.071	-0.050	11.990	0.152
		9	0.050	0.065	12.283	0.198
		10	0.162	0.103	15.438	0.117
		11	0.153	0.098	18.296	0.075
		12	0.022	-0.030	18.357	0.105
		13	-0.082	-0.066	19.192	0.117
		14	-0.058	-0.043	19.607	0.143
		15	0.084	0.048	20.510	0.153
		16	0.109	0.035	22.030	0.142
		17	0.005	-0.028	22.033	0.183
		18	-0.034	0.016	22.182	0.224
		19	-0.099	-0.091	23.487	0.217
		20	-0.075	-0.085	24.249	0.232
		21	0.112	0.090	25.938	0.209
		22	0.168	0.122	29.811	0.123
		23	0.008	0.020	29.820	0.155
		24	-0.102	-0.065	31.273	0.146
		25	-0.022	0.000	31.341	0.178
		26	-0.011	-0.071	31.358	0.215
		27	-0.012	-0.072	31.378	0.256
		28	-0.029	-0.017	31.504	0.295
		29	-0.009	0.086	31.516	0.342
		30	-0.013	0.059	31.543	0.389
		31	0.015	-0.020	31.579	0.437
		32	0.044	-0.023	31.877	0.473
		33	0.021	-0.026	31.948	0.519
		34	-0.020	0.007	32.014	0.565
		35	-0.070	-0.018	32.806	0.574
		36	-0.014	0.027	32.836	0.620

Appendix G5. CNY/USD Autocorrelation Test at Levels (2017.11-2019.08)

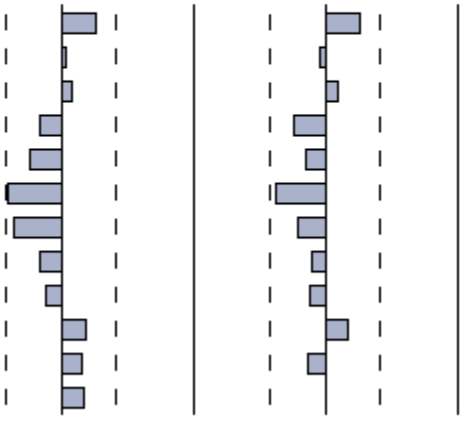
Date: 09/24/19 Time: 11:03
Sample: 2017M11 2019M08
Included observations: 22



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.795	0.795	15.906	0.000
		2	0.609	-0.064	25.702	0.000
		3	0.390	-0.203	29.939	0.000
		4	0.128	-0.291	30.418	0.000
		5	-0.051	0.009	30.499	0.000
		6	-0.173	0.025	31.488	0.000
		7	-0.197	0.139	32.850	0.000
		8	-0.126	0.149	33.448	0.000
		9	-0.075	-0.111	33.677	0.000
		10	-0.031	-0.151	33.720	0.000
		11	-0.042	-0.203	33.806	0.000
		12	-0.050	0.080	33.936	0.001

Appendix G6. CNY/USD Autocorrelation Test at First Difference (2017.11-2019.08)

Date: 09/24/19 Time: 11:03
Sample: 2017M11 2019M08
Included observations: 21



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.275	0.275	1.8262	0.177
		2	0.043	-0.035	1.8740	0.392
		3	0.089	0.093	2.0862	0.555
		4	-0.170	-0.239	2.9048	0.574
		5	-0.238	-0.139	4.6193	0.464
		6	-0.414	-0.383	10.145	0.119
		7	-0.372	-0.205	14.909	0.037
		8	-0.157	-0.106	15.830	0.045
		9	-0.121	-0.122	16.422	0.059
		10	0.193	0.182	18.065	0.054
		11	0.162	-0.127	19.333	0.055
		12	0.185	0.009	21.172	0.048

Appendix G7. CNY/USD UIP Testing (2005.01-2008.10)

Dependent Variable: LOG(CNY_USD__T_3_)-LOG(CNY_USD)
Method: Least Squares
Date: 09/27/19 Time: 14:08
Sample: 2005M01 2008M10
Included observations: 46

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.011988	0.001332	-8.999072	0.0000
CNY_YIELD_1Y-US_3M	-0.000153	0.000608	-0.251924	0.8023

R-squared	0.001440	Mean dependent var	-0.011811
Adjusted R-squared	-0.021254	S.D. dependent var	0.007592
S.E. of regression	0.007672	Akaike info criterion	-6.859960
Sum squared resid	0.002590	Schwarz criterion	-6.780454
Log likelihood	159.7791	Hannan-Quinn criter.	-6.830177
F-statistic	0.063466	Durbin-Watson stat	0.494505
Prob(F-statistic)	0.802273		

Appendix G8. CNY/USD UIP Testing (2008.11-2017.10)

Dependent Variable: LOG(CNY_USD__T_3_)-LOG(CNY_USD)
Method: Least Squares
Date: 09/24/19 Time: 16:42
Sample: 2008M11 2017M10
Included observations: 108

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001919	0.002068	0.928207	0.3554
CNY_1_YR_YIELD-US_1Y	0.000524	0.000852	0.614305	0.5403

R-squared	0.003547	Mean dependent var	0.003105
Adjusted R-squared	-0.005853	S.D. dependent var	0.007675
S.E. of regression	0.007698	Akaike info criterion	-6.877442
Sum squared resid	0.006281	Schwarz criterion	-6.827773
Log likelihood	373.3819	Hannan-Quinn criter.	-6.857303
F-statistic	0.377370	Durbin-Watson stat	0.472346
Prob(F-statistic)	0.540330		

Appendix G9. CNY/USD UIP Testing (2017.11-2019.08)

Dependent Variable: LOG(CNY_USD__T_3_)-LOG(CNY_USD)
Method: Least Squares
Date: 09/24/19 Time: 16:53
Sample: 2017M11 2019M08
Included observations: 22

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.002120	0.000566	3.747112	0.0013
CNY_1Y_YIELD-US_1Y_YIELD	0.002648	0.000606	4.367352	0.0003

R-squared	0.488148	Mean dependent var	0.003899
Adjusted R-squared	0.462555	S.D. dependent var	0.002512
S.E. of regression	0.001842	Akaike info criterion	-9.669668
Sum squared resid	6.78E-05	Schwarz criterion	-9.570482
Log likelihood	108.3663	Hannan-Quinn criter.	-9.646302
F-statistic	19.07377	Durbin-Watson stat	2.323270
Prob(F-statistic)	0.000298		

Appendix. H1. ZAR/EUR Autocorrelation Test at Levels (2005.01-2015.02)

Date: 09/25/19 Time: 08:52
Sample: 2005M01 2015M02
Included observations: 122

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.962	0.962	115.75	0.000
		2	0.924	-0.030	223.29	0.000
		3	0.881	-0.078	321.90	0.000
		4	0.834	-0.075	411.05	0.000
		5	0.792	0.041	492.07	0.000
		6	0.749	-0.022	565.26	0.000
		7	0.711	0.026	631.71	0.000
		8	0.666	-0.117	690.54	0.000
		9	0.614	-0.128	740.97	0.000
		10	0.559	-0.060	783.24	0.000
		11	0.503	-0.033	817.76	0.000
		12	0.440	-0.134	844.40	0.000
		13	0.371	-0.144	863.47	0.000
		14	0.305	-0.005	876.53	0.000
		15	0.245	0.031	885.02	0.000
		16	0.195	0.103	890.42	0.000
		17	0.149	0.022	893.63	0.000
		18	0.113	0.078	895.51	0.000
		19	0.078	-0.030	896.39	0.000
		20	0.043	0.036	896.67	0.000
		21	0.007	-0.033	896.67	0.000
		22	-0.033	-0.097	896.84	0.000
		23	-0.067	0.019	897.53	0.000
		24	-0.100	-0.019	899.06	0.000
		25	-0.126	0.008	901.55	0.000
		26	-0.155	-0.140	905.34	0.000
		27	-0.171	0.107	909.98	0.000
		28	-0.189	-0.119	915.71	0.000
		29	-0.212	-0.102	923.01	0.000
		30	-0.226	0.068	931.41	0.000
		31	-0.236	0.098	940.66	0.000
		32	-0.247	-0.055	950.90	0.000
		33	-0.259	-0.016	962.32	0.000
		34	-0.271	-0.010	974.92	0.000
		35	-0.278	0.011	988.40	0.000
		36	-0.283	0.038	1002.5	0.000

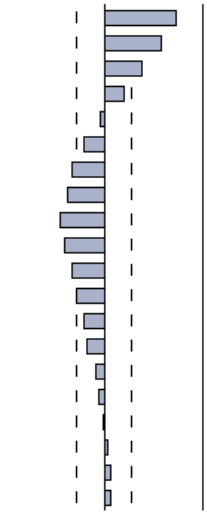
Appendix. H2. ZAR/EUR Autocorrelation Test at First Difference (2005.01-2015.02)

Date: 09/25/19 Time: 08:53
Sample: 2005M01 2015M02
Included observations: 121

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.017	-0.017	0.0369	0.848
		2	0.047	0.047	0.3128	0.855
		3	0.063	0.065	0.8109	0.847
		4	-0.042	-0.042	1.0306	0.905
		5	-0.096	-0.105	2.2200	0.818
		6	-0.085	-0.091	3.1633	0.788
		7	0.076	0.090	3.9176	0.789
		8	0.093	0.123	5.0596	0.751
		9	0.103	0.109	6.4751	0.692
		10	-0.049	-0.091	6.8008	0.744
		11	0.132	0.089	9.1683	0.606
		12	0.064	0.086	9.7276	0.640
		13	-0.122	-0.079	11.789	0.545
		14	-0.046	-0.059	12.087	0.599
		15	-0.157	-0.180	15.532	0.414
		16	0.036	0.045	15.721	0.473
		17	-0.130	-0.088	18.143	0.380
		18	-0.054	-0.077	18.566	0.419
		19	0.051	-0.015	18.941	0.461
		20	0.138	0.121	21.753	0.354
		21	0.005	0.042	21.757	0.414
		22	-0.003	0.013	21.758	0.474
		23	-0.071	-0.138	22.518	0.489
		24	-0.114	-0.077	24.509	0.433
		25	0.027	0.121	24.624	0.484
		26	-0.177	-0.068	29.515	0.288
		27	0.008	-0.046	29.526	0.336
		28	0.119	0.039	31.793	0.283
		29	-0.142	-0.150	35.072	0.202
		30	-0.058	-0.100	35.614	0.221
		31	0.060	0.040	36.208	0.238
		32	0.017	0.006	36.259	0.277
		33	-0.096	-0.060	37.815	0.259
		34	0.008	0.014	37.825	0.299
		35	-0.059	-0.023	38.428	0.317
		36	0.036	0.023	38.657	0.351

Appendix. H3. ZAR/EUR Autocorrelation Test at Levels (2015.03-2018.12)

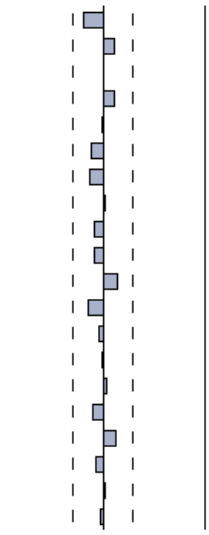
Date: 09/25/19 Time: 08:58
Sample: 2015M03 2018M12
Included observations: 46



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.757	0.757	28.145	0.000
		2	0.614	0.094	47.046	0.000
		3	0.406	-0.205	55.500	0.000
		4	0.205	-0.172	57.716	0.000
		5	-0.038	-0.270	57.795	0.000
		6	-0.212	-0.103	60.284	0.000
		7	-0.332	-0.009	66.506	0.000
		8	-0.392	0.000	75.439	0.000
		9	-0.462	-0.164	88.155	0.000
		10	-0.424	0.013	99.162	0.000
		11	-0.330	0.097	106.02	0.000
		12	-0.291	-0.180	111.52	0.000
		13	-0.217	-0.067	114.67	0.000
		14	-0.178	-0.160	116.86	0.000
		15	-0.087	0.025	117.41	0.000
		16	-0.051	-0.023	117.60	0.000
		17	-0.002	-0.013	117.60	0.000
		18	0.037	-0.038	117.71	0.000
		19	0.076	-0.055	118.18	0.000
		20	0.078	-0.025	118.70	0.000

Appendix. H4. ZAR/EUR Autocorrelation Test at First Difference (2015.03-2018.12)

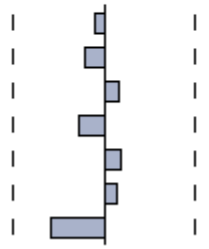
Date: 09/25/19 Time: 08:59
Sample: 2015M03 2018M12
Included observations: 45



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.202	-0.202	1.9614	0.161
		2	0.108	0.070	2.5378	0.281
		3	0.009	0.045	2.5416	0.468
		4	0.115	0.123	3.2211	0.522
		5	-0.007	0.034	3.2239	0.666
		6	-0.114	-0.140	3.9281	0.686
		7	-0.128	-0.205	4.8431	0.679
		8	0.017	-0.047	4.8589	0.773
		9	-0.091	-0.059	5.3420	0.804
		10	-0.090	-0.075	5.8336	0.829
		11	0.146	0.194	7.1683	0.785
		12	-0.155	-0.083	8.6994	0.728
		13	-0.039	-0.162	8.8004	0.788
		14	-0.016	-0.071	8.8182	0.843
		15	0.040	-0.016	8.9288	0.881
		16	-0.106	-0.124	9.7452	0.880
		17	0.124	0.167	10.907	0.861
		18	-0.079	0.025	11.394	0.877
		19	0.031	-0.114	11.475	0.907
		20	-0.025	-0.053	11.527	0.931

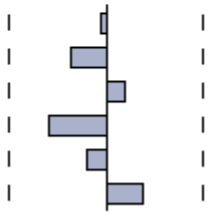
Appendix. H5. ZAR/EUR Autocorrelation Test at Levels (2019.01-2019.08)

Date: 09/25/19 Time: 08:57
Sample: 2019M01 2019M08
Included observations: 8

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.069	-0.069	0.0550	0.815
		2	-0.150	-0.156	0.3552	0.837
		3	0.116	0.096	0.5720	0.903
		4	-0.195	-0.211	1.3311	0.856
		5	0.129	0.151	1.7758	0.879
		6	0.094	0.029	2.1319	0.907
		7	-0.426	-0.369	16.629	0.020

Appendix. H6. ZAR/EUR Autocorrelation Test at First Difference (2019.01-2019.08)

Date: 09/25/19 Time: 08:58
Sample: 2019M01 2019M08
Included observations: 7

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.049	-0.049	0.0248	0.875
		2	-0.276	-0.279	0.9865	0.611
		3	0.143	0.122	1.3088	0.727
		4	-0.446	-0.564	5.4874	0.241
		5	-0.154	-0.119	6.2370	0.284
		6	0.282	-0.122	11.252	0.081

Appendix H7. ZAR/EUR UIP Test (2005.01-2015.02)

Dependent Variable: LOG(ZAR_EUR__T_3_)-LOG(ZAR_EUR)
Method: Least Squares
Date: 09/25/19 Time: 11:03
Sample: 2005M01 2015M02
Included observations: 122

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.007363	0.000436	16.89821	0.0000
SA_3M_YIELD-US_3M_YIELD	0.001226	6.82E-05	17.98306	0.0000

R-squared	0.729358	Mean dependent var	0.014775
Adjusted R-squared	0.727103	S.D. dependent var	0.002985
S.E. of regression	0.001559	Akaike info criterion	-10.07287
Sum squared resid	0.000292	Schwarz criterion	-10.02690
Log likelihood	616.4449	Hannan-Quinn criter.	-10.05420
F-statistic	323.3905	Durbin-Watson stat	0.589193
Prob(F-statistic)	0.000000		

Appendix H8. ZAR/EUR UIP Test (2015.03-2018.12)

Dependent Variable: LOG(ZAR_EUR__T_3_)-LOG(ZAR_EUR)
Method: Least Squares
Date: 09/25/19 Time: 11:06
Sample: 2015M03 2018M12
Included observations: 46

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.016697	0.001716	9.729769	0.0000
SA_3M_YIELD_-US_3M_YIELD	0.000540	0.000285	1.898511	0.0642

R-squared	0.075715	Mean dependent var	0.019909
Adjusted R-squared	0.054708	S.D. dependent var	0.002005
S.E. of regression	0.001949	Akaike info criterion	-9.600457
Sum squared resid	0.000167	Schwarz criterion	-9.520950
Log likelihood	222.8105	Hannan-Quinn criter.	-9.570673
F-statistic	3.604343	Durbin-Watson stat	0.734107
Prob(F-statistic)	0.064200		

Appendix H9. ZAR/EUR UIP Test (2019.01-2019.08)

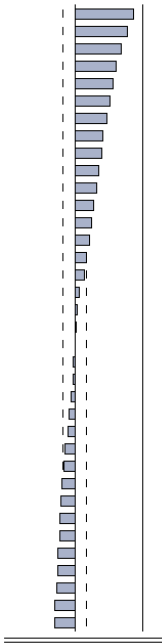
Dependent Variable: LOG(ZAR_EUR_T_3)-LOG(ZAR_EUR)
Method: Least Squares
Date: 09/25/19 Time: 11:11
Sample (adjusted): 2019M01 2019M08
Included observations: 8 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.026673	0.013879	1.921906	0.1030
SA_3M_YIELD-US_3M_YIELD	-0.002063	0.003101	-0.665059	0.5307

R-squared	0.068656	Mean dependent var	0.017462
Adjusted R-squared	-0.086568	S.D. dependent var	0.002417
S.E. of regression	0.002519	Akaike info criterion	-8.917510
Sum squared resid	3.81E-05	Schwarz criterion	-8.897649
Log likelihood	37.67004	Hannan-Quinn criter.	-9.051460
F-statistic	0.442304	Durbin-Watson stat	2.636000
Prob(F-statistic)	0.530730		

Appendix I1. BRL/EUR Autocorrelation Test at Levels (2005.01-2015.02)

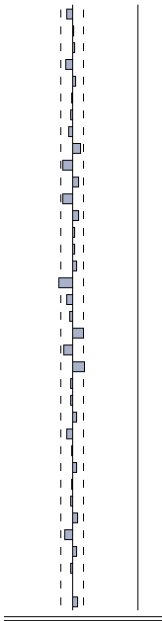
Date: 09/25/19 Time: 14:32
Sample: 2005M01 2015M02
Included observations: 122



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.901	0.901	101.47	0.000
		2	0.818	0.033	185.79	0.000
		3	0.721	-0.112	251.91	0.000
		4	0.634	-0.013	303.51	0.000
		5	0.583	0.151	347.52	0.000
		6	0.534	-0.006	384.65	0.000
		7	0.487	-0.039	415.91	0.000
		8	0.438	-0.037	441.37	0.000
		9	0.411	0.122	463.97	0.000
		10	0.363	-0.112	481.76	0.000
		11	0.339	0.066	497.44	0.000
		12	0.291	-0.123	509.08	0.000
		13	0.263	0.098	518.70	0.000
		14	0.231	-0.056	526.17	0.000
		15	0.188	-0.069	531.17	0.000
		16	0.141	-0.104	534.00	0.000
		17	0.070	-0.111	534.70	0.000
		18	0.041	0.153	534.94	0.000
		19	0.018	0.046	534.99	0.000
		20	0.007	-0.061	535.00	0.000
		21	-0.022	-0.118	535.07	0.000
		22	-0.026	0.149	535.17	0.000
		23	-0.061	-0.119	535.74	0.000
		24	-0.087	-0.049	536.89	0.000
		25	-0.106	-0.026	538.63	0.000
		26	-0.142	-0.006	541.82	0.000
		27	-0.163	-0.044	546.08	0.000
		28	-0.189	0.003	551.82	0.000
		29	-0.206	-0.070	558.74	0.000
		30	-0.224	0.039	566.99	0.000
		31	-0.234	-0.021	576.11	0.000
		32	-0.261	-0.070	587.57	0.000
		33	-0.269	-0.018	599.86	0.000
		34	-0.279	-0.030	613.29	0.000
		35	-0.296	-0.036	628.52	0.000
		36	-0.308	-0.040	645.26	0.000

Appendix I2. BRL/EUR Autocorrelation Test at First Difference (2005.01-2015.02)

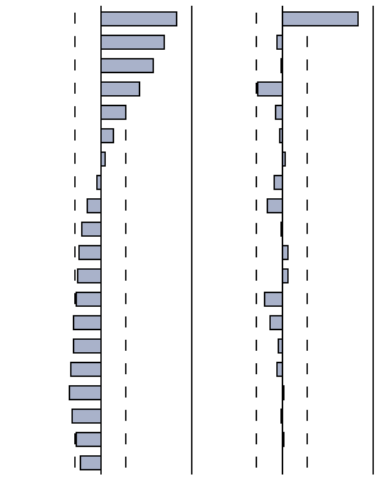
Date: 09/25/19 Time: 14:33
Sample: 2005M01 2015M02
Included observations: 121



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.086	-0.086	0.9164	0.338
		2	0.025	0.018	0.9933	0.609
		3	0.034	0.038	1.1423	0.767
		4	-0.103	-0.099	2.5022	0.644
		5	0.059	0.041	2.9434	0.709
		6	-0.005	0.007	2.9463	0.816
		7	-0.017	-0.013	2.9838	0.886
		8	-0.059	-0.076	3.4456	0.903
		9	0.138	0.141	5.9645	0.743
		10	-0.145	-0.128	8.7751	0.554
		11	0.094	0.075	9.9664	0.533
		12	-0.151	-0.168	13.077	0.363
		13	0.104	0.149	14.559	0.336
		14	0.039	-0.013	14.767	0.394
		15	0.039	0.107	14.978	0.453
		16	0.079	0.013	15.867	0.462
		17	-0.211	-0.154	22.243	0.176
		18	-0.093	-0.187	23.497	0.172
		19	-0.039	0.012	23.719	0.207
		20	0.174	0.163	28.172	0.105
		21	-0.137	-0.086	30.951	0.074
		22	0.201	0.146	36.998	0.024
		23	-0.021	0.027	37.065	0.032
		24	-0.024	-0.029	37.154	0.042
		25	0.078	0.001	38.093	0.045
		26	-0.094	0.005	39.465	0.044
		27	-0.004	-0.043	39.467	0.057
		28	0.073	0.101	40.326	0.062
		29	-0.001	-0.104	40.326	0.079
		30	-0.022	0.080	40.406	0.097
		31	0.087	-0.000	41.667	0.096
		32	-0.122	0.051	44.136	0.075
		33	0.082	0.016	45.272	0.076
		34	-0.017	0.018	45.321	0.093
		35	0.014	-0.077	45.353	0.113
		36	0.085	0.035	46.620	0.111

Appendix I3. BRL/EUR Autocorrelation at Levels (2015.03-2018.12)

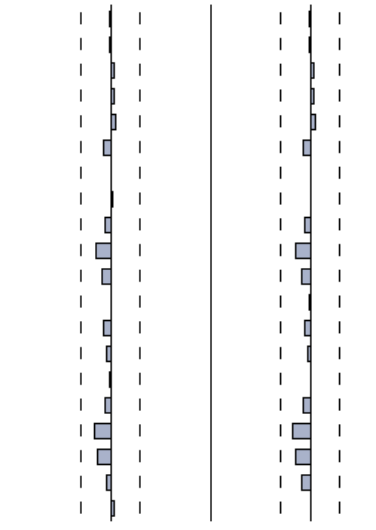
Date: 09/25/19 Time: 14:34
Sample: 2015M03 2018M12
Included observations: 46



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.863	0.863	36.524	0.000
		2	0.728	-0.065	63.103	0.000
		3	0.612	-0.003	82.323	0.000
		4	0.443	-0.279	92.646	0.000
		5	0.283	-0.079	96.965	0.000
		6	0.156	-0.019	98.302	0.000
		7	0.055	0.048	98.476	0.000
		8	-0.045	-0.095	98.594	0.000
		9	-0.152	-0.163	99.965	0.000
		10	-0.220	-0.010	102.92	0.000
		11	-0.248	0.078	106.81	0.000
		12	-0.255	0.076	111.05	0.000
		13	-0.286	-0.196	116.51	0.000
		14	-0.307	-0.129	122.99	0.000
		15	-0.307	-0.037	129.72	0.000
		16	-0.333	-0.061	137.87	0.000
		17	-0.345	0.020	146.92	0.000
		18	-0.325	-0.011	155.25	0.000
		19	-0.283	0.033	161.80	0.000
		20	-0.234	0.008	166.45	0.000

Appendix I4. BRL/EUR Autocorrelation at First Difference (2015.03-2018.12)

Date: 09/25/19 Time: 14:36
Sample: 2015M03 2018M12
Included observations: 45



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.016	-0.016	0.0123	0.912
		2	-0.008	-0.008	0.0156	0.992
		3	0.043	0.043	0.1087	0.991
		4	0.044	0.045	0.2079	0.995
		5	0.056	0.059	0.3745	0.996
		6	-0.071	-0.071	0.6503	0.996
		7	0.006	0.000	0.6521	0.999
		8	0.018	0.010	0.6700	1.000
		9	-0.056	-0.055	0.8561	1.000
		10	-0.146	-0.147	2.1439	0.995
		11	-0.091	-0.094	2.6584	0.995
		12	0.006	-0.002	2.6610	0.998
		13	-0.070	-0.057	2.9849	0.998
		14	-0.045	-0.022	3.1228	0.999
		15	-0.011	0.002	3.1316	0.999
		16	-0.062	-0.069	3.4136	1.000
		17	-0.159	-0.175	5.3312	0.997
		18	-0.130	-0.145	6.6464	0.993
		19	-0.043	-0.086	6.7953	0.995
		20	0.045	0.009	6.9701	0.997

Appendix I5. BRL/EUR Autocorrelation Test at Levels (2019.01-2019.08)

Date: 09/25/19 Time: 14:38
Sample: 2019M01 2019M08
Included observations: 8

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.153	-0.153	0.2672	0.605
		2	-0.075	-0.101	0.3418	0.843
		3	-0.077	-0.109	0.4378	0.932
		4	-0.049	-0.093	0.4857	0.975
		5	0.151	0.115	1.0972	0.954
		6	0.056	0.087	1.2244	0.976
		7	-0.354	-0.338	11.231	0.129

Appendix I6. BRL/EUR Autocorrelation Test at First Difference (2019.01-2019.08)

Date: 09/25/19 Time: 14:39
Sample: 2019M01 2019M08
Included observations: 7

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.279	-0.279	0.8191	0.365
		2	-0.046	-0.135	0.8459	0.655
		3	-0.095	-0.163	0.9887	0.804
		4	-0.248	-0.379	2.2802	0.684
		5	0.085	-0.210	2.5067	0.775
		6	0.084	-0.093	2.9501	0.815

Appendix I7. BRL/EUR UIP Test (2006.02-2011.08)

Dependent Variable: LOG(FW_BRL_EUR_)-LOG(BRL_EUR)
Method: Least Squares
Date: 09/25/19 Time: 18:34
Sample: 2006M02 2011M08
Included observations: 67

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.010462	0.005068	-2.064110	0.0430
BRL_3M-US_3M	0.002604	0.000506	5.149503	0.0000

R-squared	0.289752	Mean dependent var	0.015208
Adjusted R-squared	0.278826	S.D. dependent var	0.008834
S.E. of regression	0.007502	Akaike info criterion	-6.917874
Sum squared resid	0.003658	Schwarz criterion	-6.852062
Log likelihood	233.7488	Hannan-Quinn criter.	-6.891832
F-statistic	26.51738	Durbin-Watson stat	0.431265
Prob(F-statistic)	0.000003		

Appendix I8. BRL/EUR UIP Test (2016.03-2018.12)

Dependent Variable: LOG(BRL_EUR__T_3_)-LOG(BRL_EUR)
Method: Least Squares
Date: 09/25/19 Time: 19:34
Sample: 2016M03 2018M12
Included observations: 34

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.007999	0.000595	13.44652	0.0000
BRL_3M-US_3M	0.001651	6.32E-05	26.13568	0.0000

R-squared	0.955249	Mean dependent var	0.022140
Adjusted R-squared	0.953851	S.D. dependent var	0.006709
S.E. of regression	0.001441	Akaike info criterion	-10.18955
Sum squared resid	6.65E-05	Schwarz criterion	-10.09977
Log likelihood	175.2224	Hannan-Quinn criter.	-10.15893
F-statistic	683.0736	Durbin-Watson stat	1.357468
Prob(F-statistic)	0.000000		

Appendix I9. BRL/EUR UIP Test (2019.01-2019.08)

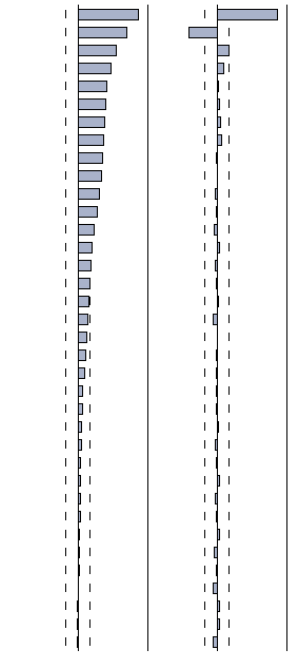
Dependent Variable: LOG(FW_BRL_EUR)-LOG(BRL_EUR)
Method: Least Squares
Date: 09/25/19 Time: 19:36
Sample: 2019M01 2019M08
Included observations: 8

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.002527	0.007853	0.321740	0.7586
BRL_3M-US_3M	0.002995	0.001958	1.529377	0.1770

R-squared	0.280489	Mean dependent var	0.014528
Adjusted R-squared	0.160570	S.D. dependent var	0.000954
S.E. of regression	0.000874	Akaike info criterion	-11.03399
Sum squared resid	4.59E-06	Schwarz criterion	-11.01413
Log likelihood	46.13597	Hannan-Quinn criter.	-11.16794
F-statistic	2.338993	Durbin-Watson stat	0.833105
Prob(F-statistic)	0.177041		

Appendix J1. RUB/EUR Autocorrelation Test at Levels (2005.01-2015.02)

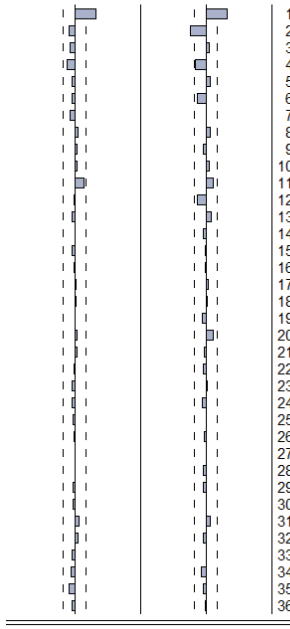
Date: 09/26/19 Time: 11:12
Sample: 2005M01 2015M02
Included observations: 122



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.897	0.897	100.56	0.000
		2	0.723	-0.413	166.54	0.000
		3	0.577	0.187	208.81	0.000
		4	0.488	0.099	239.37	0.000
		5	0.441	0.026	264.57	0.000
		6	0.414	0.043	286.93	0.000
		7	0.395	0.050	307.46	0.000
		8	0.385	0.071	327.16	0.000
		9	0.375	-0.006	346.03	0.000
		10	0.357	0.000	363.27	0.000
		11	0.327	-0.018	377.87	0.000
		12	0.290	-0.011	389.44	0.000
		13	0.249	-0.039	398.01	0.000
		14	0.218	0.046	404.65	0.000
		15	0.195	-0.032	410.04	0.000
		16	0.178	-0.004	414.54	0.000
		17	0.167	0.030	418.54	0.000
		18	0.152	-0.057	421.89	0.000
		19	0.133	0.008	424.49	0.000
		20	0.114	-0.010	426.40	0.000
		21	0.095	-0.007	427.75	0.000
		22	0.079	-0.001	428.70	0.000
		23	0.066	-0.004	429.37	0.000
		24	0.060	0.029	429.93	0.000
		25	0.056	-0.024	430.41	0.000
		26	0.049	-0.008	430.79	0.000
		27	0.045	0.035	431.11	0.000
		28	0.041	-0.022	431.38	0.000
		29	0.033	-0.015	431.56	0.000
		30	0.029	0.045	431.70	0.000
		31	0.025	-0.037	431.80	0.000
		32	0.018	-0.002	431.85	0.000
		33	0.001	-0.063	431.85	0.000
		34	-0.014	0.038	431.89	0.000
		35	-0.014	0.049	431.92	0.000
		36	-0.009	-0.059	431.94	0.000

Appendix J2. RUB/EUR Autocorrelation Test at First Difference (2005.01-2015.02)

Date: 09/26/19 Time: 11:13
Sample: 2005M01 2015M02
Included observations: 121



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.343	0.343	14.556	0.000
		2	-0.098	-0.244	15.756	0.000
		3	-0.077	0.058	16.507	0.001
		4	-0.117	-0.156	18.253	0.001
		5	-0.033	0.076	18.396	0.002
		6	-0.045	-0.125	18.663	0.005
		7	-0.067	0.001	19.256	0.007
		8	0.060	0.067	19.733	0.011
		9	0.036	-0.043	19.910	0.018
		10	0.033	0.063	20.060	0.029
		11	0.146	0.120	22.928	0.018
		12	-0.015	-0.124	22.960	0.028
		13	-0.035	0.087	23.128	0.040
		14	0.008	-0.034	23.137	0.058
		15	-0.049	-0.001	23.477	0.075
		16	-0.006	-0.003	23.482	0.101
		17	0.028	0.041	23.592	0.131
		18	0.031	0.025	23.734	0.164
		19	0.014	-0.051	23.762	0.205
		20	0.043	0.108	24.034	0.241
		21	0.038	-0.029	24.252	0.281
		22	-0.012	-0.033	24.274	0.333
		23	-0.034	0.029	24.453	0.379
		24	-0.042	-0.050	24.718	0.421
		25	-0.019	0.012	24.776	0.475
		26	-0.010	-0.019	24.792	0.531
		27	0.001	0.016	24.792	0.586
		28	0.001	-0.034	24.793	0.639
		29	-0.020	-0.036	24.856	0.686
		30	-0.031	0.008	25.011	0.725
		31	0.081	0.079	26.089	0.717
		32	0.052	-0.043	26.535	0.739
		33	-0.042	0.000	26.840	0.767
		34	-0.065	-0.068	27.558	0.775
		35	-0.092	-0.036	29.020	0.751
		36	-0.033	-0.003	29.214	0.781

Appendix J3. RUB/EUR Autocorrelation Test at Levels (2015.03-2018.12)

Date: 09/26/19 Time: 11:14
Sample: 2015M03 2018M12
Included observations: 46

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.824	0.824	33.283	0.000
		2	0.588	-0.282	50.605	0.000
		3	0.397	0.031	58.701	0.000
		4	0.273	0.033	62.615	0.000
		5	0.156	-0.130	63.919	0.000
		6	0.040	-0.066	64.008	0.000
		7	-0.100	-0.188	64.570	0.000
		8	-0.237	-0.123	67.835	0.000
		9	-0.354	-0.122	75.314	0.000
		10	-0.381	0.093	84.215	0.000
		11	-0.365	-0.056	92.614	0.000
		12	-0.370	-0.153	101.48	0.000
		13	-0.393	-0.072	111.81	0.000
		14	-0.408	-0.105	123.27	0.000
		15	-0.382	-0.017	133.64	0.000
		16	-0.322	-0.054	141.25	0.000
		17	-0.239	-0.014	145.60	0.000
		18	-0.181	-0.128	148.19	0.000
		19	-0.125	0.027	149.48	0.000
		20	-0.058	0.018	149.77	0.000

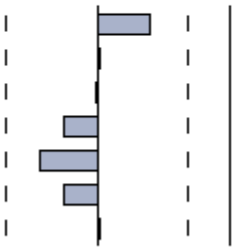
Appendix J4. RUB/EUR Autocorrelation Test at Levels (2015.03-2018.12)

Date: 09/26/19 Time: 11:14
Sample: 2015M03 2018M12
Included observations: 45

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.208	0.208	2.0754	0.150
		2	-0.170	-0.222	3.4919	0.174
		3	-0.230	-0.155	6.1550	0.104
		4	0.031	0.093	6.2055	0.184
		5	0.194	0.113	8.2041	0.145
		6	0.107	0.023	8.8286	0.183
		7	-0.058	-0.021	9.0160	0.252
		8	-0.167	-0.089	10.601	0.225
		9	-0.051	-0.003	10.751	0.293
		10	-0.059	-0.140	10.958	0.361
		11	0.055	0.040	11.146	0.431
		12	-0.015	-0.053	11.160	0.515
		13	-0.079	-0.057	11.569	0.563
		14	-0.120	-0.074	12.554	0.562
		15	-0.202	-0.208	15.426	0.421
		16	-0.061	-0.050	15.699	0.474
		17	0.041	-0.030	15.826	0.536
		18	0.038	-0.056	15.941	0.597
		19	0.016	0.060	15.962	0.660
		20	-0.079	-0.072	16.491	0.686

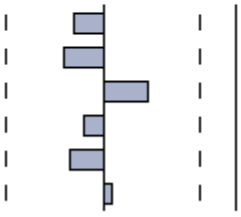
Appendix J5. RUB/EUR Autocorrelation Test at Levels (2019.01-2019.08)

Date: 09/26/19 Time: 11:16
Sample: 2019M01 2019M08
Included observations: 8

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.424	0.424	2.0584	0.151
		2	0.020	-0.195	2.0637	0.356
		3	-0.011	0.078	2.0657	0.559
		4	-0.257	-0.356	3.3828	0.496
		5	-0.443	-0.233	8.6163	0.125
		6	-0.259	-0.019	11.293	0.080
		7	0.025	0.137	11.343	0.124

Appendix J6. RUB/EUR Autocorrelation Test at First Difference (2019.01-2019.08)

Date: 09/26/19 Time: 11:16
Sample: 2019M01 2019M08
Included observations: 7

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.228	-0.228	0.5464	0.460
		2	-0.298	-0.370	1.6689	0.434
		3	0.352	0.213	3.6226	0.305
		4	-0.149	-0.139	4.0892	0.394
		5	-0.257	-0.187	6.1704	0.290
		6	0.081	-0.219	6.5788	0.362

Appendix J7. RUB/EUR UIP Testing (2008.04-2015.02)

Dependent Variable: LOG(RUB_EUR__T_3_)-LOG(RUB_EUR)
Method: Least Squares
Date: 09/26/19 Time: 13:46
Sample: 2008M04 2015M02
Included observations: 83

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000593	0.003816	-0.155504	0.8768
RUB_3M_YIELD-US_3M_YIE...	0.002261	0.000385	5.866039	0.0000

R-squared	0.298157	Mean dependent var	0.018567
Adjusted R-squared	0.289492	S.D. dependent var	0.021327
S.E. of regression	0.017977	Akaike info criterion	-5.175644
Sum squared resid	0.026177	Schwarz criterion	-5.117359
Log likelihood	216.7892	Hannan-Quinn criter.	-5.152229
F-statistic	34.41041	Durbin-Watson stat	1.972233
Prob(F-statistic)	0.000000		

Appendix J8. RUB/EUR UIP Testing (2015.03-2018.12)

Dependent Variable: LOG(RUB_EUR__T_3_)-LOG(RUB_EUR)
Method: Least Squares
Date: 09/26/19 Time: 13:48
Sample: 2015M03 2018M12
Included observations: 46

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.007366	0.000715	10.30181	0.0000
RUB_3M_YIELD-US_3M_YIE...	0.001889	7.59E-05	24.89027	0.0000

R-squared	0.933688	Mean dependent var	0.024296
Adjusted R-squared	0.932180	S.D. dependent var	0.005744
S.E. of regression	0.001496	Akaike info criterion	-10.12986
Sum squared resid	9.84E-05	Schwarz criterion	-10.05035
Log likelihood	234.9867	Hannan-Quinn criter.	-10.10007
F-statistic	619.5253	Durbin-Watson stat	0.797207
Prob(F-statistic)	0.000000		

Appendix J9. RUB/EUR UIP Testing (2019.01-2019.08)

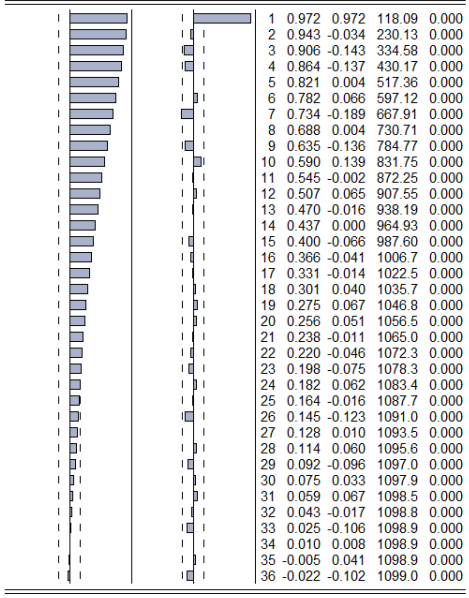
Dependent Variable: LOG(RUB_EUR_T_3_)-LOG(RUB_EUR)
Method: Least Squares
Date: 09/26/19 Time: 13:49
Sample (adjusted): 2019M01 2019M08
Included observations: 8 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.004615	0.007436	0.620681	0.5576
RUB_3M_YIELD-US_3M_YIE...	0.002961	0.001417	2.089062	0.0817

R-squared	0.421083	Mean dependent var	0.020145
Adjusted R-squared	0.324597	S.D. dependent var	0.000616
S.E. of regression	0.000507	Akaike info criterion	-12.12543
Sum squared resid	1.54E-06	Schwarz criterion	-12.10557
Log likelihood	50.50174	Hannan-Quinn criter.	-12.25939
F-statistic	4.364181	Durbin-Watson stat	1.600497
Prob(F-statistic)	0.081704		

Appendix K1. INR/EUR Autocorrelation Test at Levels (2005.01-2015.02)

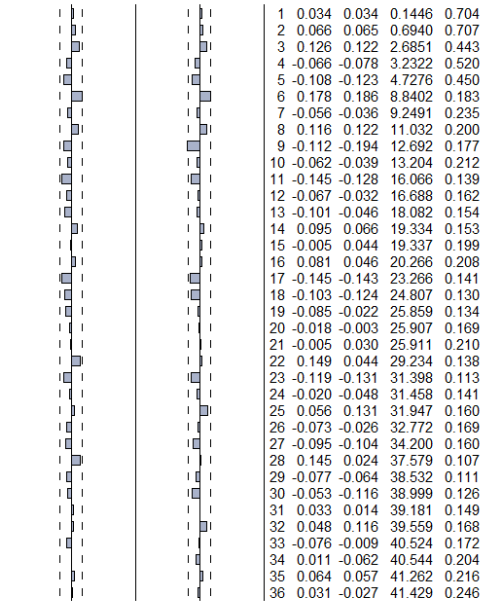
Date: 09/26/19 Time: 16:06
Sample: 2005M01 2015M02
Included observations: 122



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.972	0.972	118.09	0.000
		2	0.943	-0.034	230.13	0.000
		3	0.906	-0.143	334.58	0.000
		4	0.864	-0.137	430.17	0.000
		5	0.821	0.004	517.36	0.000
		6	0.782	0.066	597.12	0.000
		7	0.734	-0.189	667.91	0.000
		8	0.688	0.004	730.71	0.000
		9	0.635	-0.136	784.77	0.000
		10	0.590	0.139	831.75	0.000
		11	0.545	-0.002	872.25	0.000
		12	0.507	0.065	907.55	0.000
		13	0.470	-0.016	938.19	0.000
		14	0.437	0.000	964.93	0.000
		15	0.400	-0.066	987.60	0.000
		16	0.366	-0.041	1006.7	0.000
		17	0.331	-0.014	1022.5	0.000
		18	0.301	0.040	1035.7	0.000
		19	0.275	0.067	1046.8	0.000
		20	0.256	0.051	1056.5	0.000
		21	0.238	-0.011	1065.0	0.000
		22	0.220	-0.046	1072.3	0.000
		23	0.198	-0.075	1078.3	0.000
		24	0.182	0.062	1083.4	0.000
		25	0.164	-0.016	1087.7	0.000
		26	0.145	-0.123	1091.0	0.000
		27	0.128	0.010	1093.5	0.000
		28	0.114	0.060	1095.6	0.000
		29	0.092	-0.096	1097.0	0.000
		30	0.075	0.033	1097.9	0.000
		31	0.059	0.067	1098.5	0.000
		32	0.043	-0.017	1098.8	0.000
		33	0.025	-0.106	1098.9	0.000
		34	0.010	0.008	1098.9	0.000
		35	-0.005	0.041	1098.9	0.000
		36	-0.022	-0.102	1099.0	0.000

Appendix K2. INR/EUR Autocorrelation Test at First Difference (2005.01-2015.02)

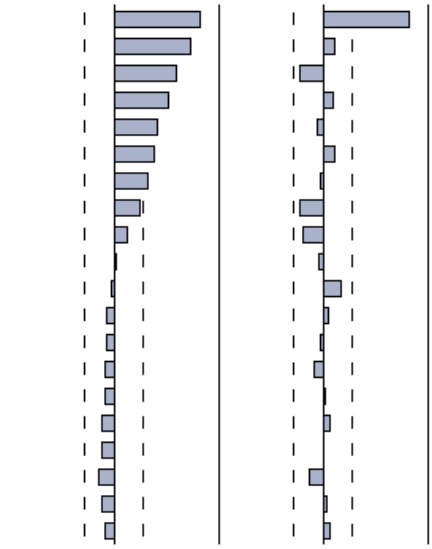
Date: 09/26/19 Time: 16:06
Sample: 2005M01 2015M02
Included observations: 121



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.034	0.034	0.1446	0.704
		2	0.066	0.065	0.6940	0.707
		3	0.126	0.122	2.6851	0.443
		4	-0.066	-0.078	3.2322	0.520
		5	-0.108	-0.123	4.7276	0.450
		6	0.178	0.186	8.8402	0.183
		7	-0.056	-0.036	9.2491	0.235
		8	0.116	0.122	11.032	0.200
		9	-0.112	-0.194	12.692	0.177
		10	-0.062	-0.039	13.204	0.212
		11	-0.145	-0.128	16.066	0.139
		12	-0.067	-0.032	16.688	0.162
		13	-0.101	-0.046	18.082	0.154
		14	0.095	0.066	19.334	0.153
		15	-0.005	0.044	19.337	0.199
		16	0.081	0.046	20.266	0.208
		17	-0.145	-0.143	23.266	0.141
		18	-0.103	-0.124	24.807	0.130
		19	-0.085	-0.022	25.859	0.134
		20	-0.018	-0.003	25.907	0.169
		21	-0.005	0.030	25.911	0.210
		22	0.149	0.044	29.234	0.138
		23	-0.119	-0.131	31.398	0.113
		24	-0.020	-0.048	31.458	0.141
		25	0.056	0.131	31.947	0.160
		26	-0.073	-0.026	32.772	0.169
		27	-0.095	-0.104	34.200	0.160
		28	0.145	0.024	37.579	0.107
		29	-0.077	-0.064	38.532	0.111
		30	-0.053	-0.116	38.999	0.126
		31	0.033	0.014	39.181	0.149
		32	0.048	0.116	39.559	0.168
		33	-0.076	-0.009	40.524	0.172
		34	0.011	-0.062	40.544	0.204
		35	0.064	0.057	41.262	0.216
		36	0.031	-0.027	41.429	0.246

Appendix K3. INR/EUR Autocorrelation Test at Levels (2015.03-2018.12)

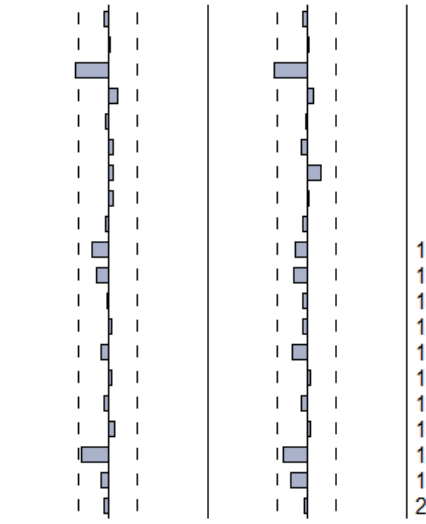
Date: 09/26/19 Time: 16:07
Sample: 2015M03 2018M12
Included observations: 46



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.860	0.860	36.302	0.000
		2	0.770	0.116	66.061	0.000
		3	0.628	-0.224	86.300	0.000
		4	0.545	0.098	101.94	0.000
		5	0.443	-0.054	112.49	0.000
		6	0.402	0.112	121.40	0.000
		7	0.342	-0.021	128.01	0.000
		8	0.257	-0.232	131.84	0.000
		9	0.133	-0.201	132.89	0.000
		10	0.025	-0.039	132.93	0.000
		11	-0.032	0.184	133.00	0.000
		12	-0.066	0.055	133.28	0.000
		13	-0.074	-0.027	133.65	0.000
		14	-0.086	-0.083	134.16	0.000
		15	-0.088	0.029	134.71	0.000
		16	-0.108	0.073	135.56	0.000
		17	-0.122	0.010	136.69	0.000
		18	-0.146	-0.136	138.38	0.000
		19	-0.120	0.041	139.55	0.000
		20	-0.092	0.078	140.26	0.000

Appendix K4. INR/EUR Autocorrelation Test at First Difference (2015.03-2018.12)

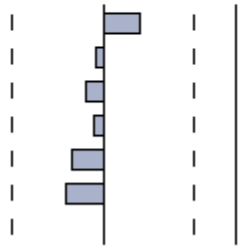
Date: 09/26/19 Time: 16:08
Sample: 2015M03 2018M12
Included observations: 45



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.043	-0.043	0.0897	0.765
		2	0.029	0.028	0.1322	0.936
		3	-0.337	-0.336	5.8627	0.118
		4	0.097	0.080	6.3432	0.175
		5	-0.032	-0.016	6.3981	0.269
		6	0.059	-0.065	6.5897	0.360
		7	0.065	0.142	6.8231	0.448
		8	0.052	0.033	6.9752	0.539
		9	-0.033	-0.037	7.0373	0.633
		10	-0.161	-0.109	8.6103	0.569
		11	-0.113	-0.125	9.3994	0.585
		12	-0.010	-0.037	9.4057	0.668
		13	0.043	-0.048	9.5272	0.732
		14	-0.073	-0.154	9.8906	0.770
		15	0.041	0.044	10.007	0.819
		16	-0.049	-0.052	10.183	0.857
		17	0.077	0.035	10.636	0.875
		18	-0.280	-0.245	16.787	0.538
		19	-0.070	-0.160	17.185	0.577
		20	-0.037	-0.025	17.303	0.633

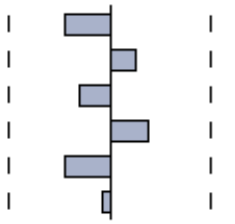
Appendix K5. INR/EUR Autocorrelation Test at Levels (2019.01-2019.08)

Date: 09/26/19 Time: 16:09
Sample: 2019M01 2019M08
Included observations: 8

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.290	0.290	0.9608	0.327
		2	-0.062	-0.159	1.0119	0.603
		3	-0.135	-0.076	1.3047	0.728
		4	-0.067	-0.011	1.3957	0.845
		5	-0.247	-0.276	3.0188	0.697
		6	-0.293	-0.188	6.4483	0.375
		7	0.014	0.123	6.4645	0.487

Appendix K6. INR/EUR Autocorrelation Test at First Difference (2019.01-2019.08)

Date: 09/26/19 Time: 16:10
Sample: 2019M01 2019M08
Included observations: 7

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.335	-0.335	1.1791	0.278
		2	0.189	0.087	1.6314	0.442
		3	-0.237	-0.170	2.5171	0.472
		4	0.288	0.181	4.2573	0.372
		5	-0.341	-0.213	7.9157	0.161
		6	-0.064	-0.332	8.1764	0.225

Appendix K7. INR/EUR UIP Test (2009.10-2015.02)

Dependent Variable: LOG(INR_EUR__T_3_)-LOG(INR_EUR)
Method: Least Squares
Date: 09/26/19 Time: 17:35
Sample (adjusted): 2009M10 2015M02
Included observations: 65 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.004773	0.003446	-1.385237	0.1709
INR_3M-US_3M	0.002649	0.000442	5.985646	0.0000

R-squared	0.362529	Mean dependent var	0.015348
Adjusted R-squared	0.352410	S.D. dependent var	0.007580
S.E. of regression	0.006100	Akaike info criterion	-7.330745
Sum squared resid	0.002344	Schwarz criterion	-7.263841
Log likelihood	240.2492	Hannan-Quinn criter.	-7.304347
F-statistic	35.82795	Durbin-Watson stat	1.032583
Prob(F-statistic)	0.000000		

Appendix K8. INR/EUR UIP Test (2015.03-2018.12)

Dependent Variable: LOG(INR_EUR__T_3_)-LOG(INR_EUR)
Method: Least Squares
Date: 09/26/19 Time: 17:40
Sample: 2015M03 2018M12
Included observations: 46

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.016237	0.003286	4.940807	0.0000
INR_3M-US_3M	3.46E-05	0.000556	0.062326	0.9506

R-squared	0.000088	Mean dependent var	0.016438
Adjusted R-squared	-0.022637	S.D. dependent var	0.004143
S.E. of regression	0.004190	Akaike info criterion	-8.069694
Sum squared resid	0.000772	Schwarz criterion	-7.990188
Log likelihood	187.6030	Hannan-Quinn criter.	-8.039911
F-statistic	0.003884	Durbin-Watson stat	1.714148
Prob(F-statistic)	0.950586		

Appendix K9. INR/EUR UIP Test (2019.01-2019.08)

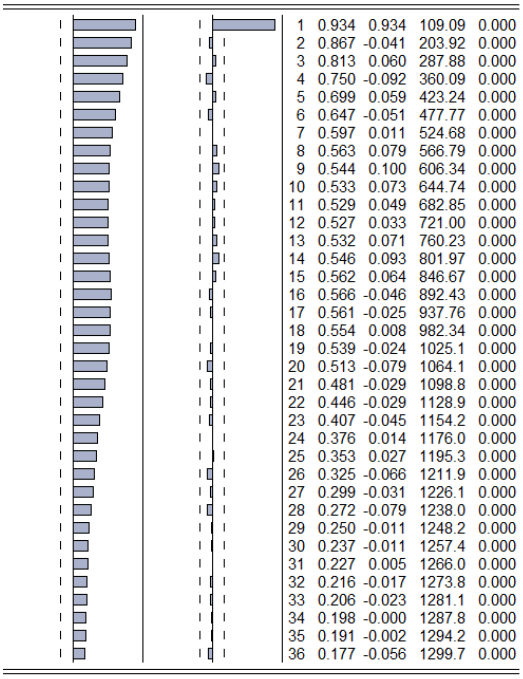
Dependent Variable: LOG(INR_EUR__T_3_)-LOG(INR_EUR)
Method: Least Squares
Date: 09/26/19 Time: 17:41
Sample: 2019M01 2019M08
Included observations: 8

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.035998	0.017883	2.013016	0.0908
INR_3M-US_3M	-0.004532	0.004667	-0.971085	0.3690

R-squared	0.135821	Mean dependent var	0.018661
Adjusted R-squared	-0.008209	S.D. dependent var	0.002867
S.E. of regression	0.002878	Akaike info criterion	-8.650780
Sum squared resid	4.97E-05	Schwarz criterion	-8.630920
Log likelihood	36.60312	Hannan-Quinn criter.	-8.784730
F-statistic	0.943006	Durbin-Watson stat	1.032835
Prob(F-statistic)	0.369009		

Appendix L1. CNY/EUR Autocorrelation Test at Levels (2005.01-2015.02)

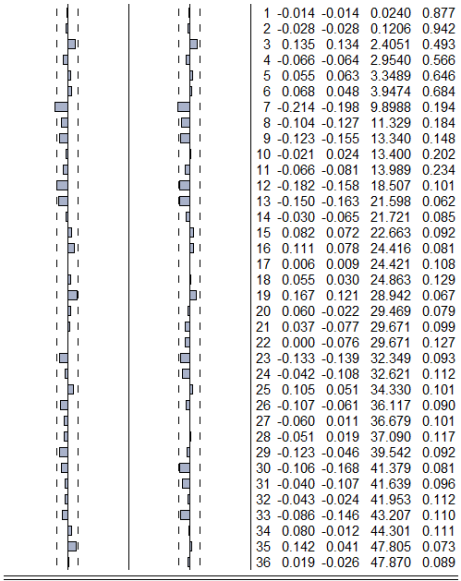
Date: 09/27/19 Time: 10:03
Sample: 2005M01 2015M02
Included observations: 122



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.934	0.934	109.09	0.000
		2	0.867	-0.041	203.92	0.000
		3	0.813	0.060	287.88	0.000
		4	0.750	-0.092	360.09	0.000
		5	0.699	0.059	423.24	0.000
		6	0.647	-0.051	477.77	0.000
		7	0.597	0.011	524.68	0.000
		8	0.563	0.079	566.79	0.000
		9	0.544	0.100	606.34	0.000
		10	0.533	0.073	644.74	0.000
		11	0.529	0.049	682.85	0.000
		12	0.527	0.033	721.00	0.000
		13	0.532	0.071	760.23	0.000
		14	0.546	0.093	801.97	0.000
		15	0.562	0.064	846.67	0.000
		16	0.566	-0.046	892.43	0.000
		17	0.561	-0.025	937.76	0.000
		18	0.554	0.008	982.34	0.000
		19	0.539	-0.024	1025.1	0.000
		20	0.513	-0.079	1064.1	0.000
		21	0.481	-0.029	1098.8	0.000
		22	0.446	-0.029	1128.9	0.000
		23	0.407	-0.045	1154.2	0.000
		24	0.376	0.014	1176.0	0.000
		25	0.353	0.027	1195.3	0.000
		26	0.325	-0.066	1211.9	0.000
		27	0.299	-0.031	1226.1	0.000
		28	0.272	-0.079	1238.0	0.000
		29	0.250	-0.011	1248.2	0.000
		30	0.237	-0.011	1257.4	0.000
		31	0.227	0.005	1266.0	0.000
		32	0.216	-0.017	1273.8	0.000
		33	0.206	-0.023	1281.1	0.000
		34	0.198	-0.000	1287.8	0.000
		35	0.191	-0.002	1294.2	0.000
		36	0.177	-0.056	1299.7	0.000

Appendix L2. CNY/EUR Autocorrelation Test at First Difference (2005.01-2015.02)

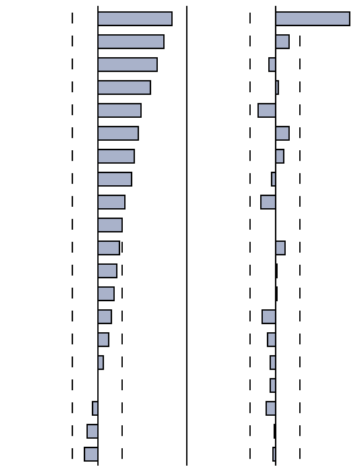
Date: 09/27/19 Time: 10:04
Sample: 2005M01 2015M02
Included observations: 121



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.014	-0.014	0.0240	0.877
		2	-0.028	-0.028	0.1206	0.942
		3	0.135	0.134	2.4051	0.493
		4	-0.066	-0.064	2.9540	0.566
		5	0.055	0.063	3.3489	0.646
		6	0.068	0.048	3.9474	0.684
		7	-0.214	-0.198	9.8988	0.194
		8	-0.104	-0.127	11.329	0.184
		9	-0.123	-0.155	13.340	0.148
		10	-0.021	0.024	13.400	0.202
		11	-0.066	-0.081	13.989	0.234
		12	-0.182	-0.158	18.507	0.101
		13	-0.150	-0.163	21.598	0.062
		14	-0.030	-0.065	21.721	0.085
		15	0.082	0.072	22.663	0.092
		16	0.111	0.078	24.416	0.081
		17	0.006	0.009	24.421	0.108
		18	0.055	0.030	24.863	0.129
		19	0.167	0.121	28.942	0.067
		20	0.060	-0.022	29.469	0.079
		21	0.037	-0.077	29.671	0.099
		22	0.000	-0.076	29.671	0.127
		23	-0.133	-0.139	32.349	0.093
		24	-0.042	-0.108	32.621	0.112
		25	0.105	0.051	34.330	0.101
		26	-0.107	-0.061	36.117	0.090
		27	-0.060	0.011	36.679	0.101
		28	-0.051	0.019	37.090	0.117
		29	-0.123	-0.046	39.542	0.092
		30	-0.106	-0.168	41.379	0.081
		31	-0.040	-0.107	41.639	0.096
		32	-0.043	-0.024	41.953	0.112
		33	-0.086	-0.146	43.207	0.110
		34	0.080	-0.012	44.301	0.111
		35	0.142	0.041	47.805	0.073
		36	0.019	-0.026	47.870	0.089

Appendix L3. CNY/EUR Autocorrelation Tests at Levels (2015.03-2018.12)

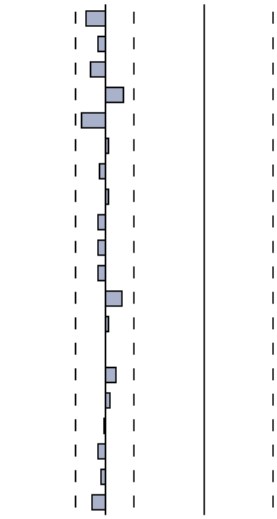
Date: 09/27/19 Time: 10:05
Sample: 2015M03 2018M12
Included observations: 46



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.861	0.861	36.411	0.000
		2	0.785	0.167	67.350	0.000
		3	0.691	-0.067	91.840	0.000
		4	0.625	0.040	112.35	0.000
		5	0.511	-0.190	126.41	0.000
		6	0.472	0.161	138.69	0.000
		7	0.438	0.104	149.55	0.000
		8	0.402	-0.042	158.95	0.000
		9	0.323	-0.171	165.18	0.000
		10	0.284	0.002	170.13	0.000
		11	0.257	0.108	174.31	0.000
		12	0.228	0.023	177.67	0.000
		13	0.201	0.021	180.37	0.000
		14	0.169	-0.141	182.34	0.000
		15	0.131	-0.090	183.56	0.000
		16	0.072	-0.052	183.95	0.000
		17	0.008	-0.057	183.95	0.000
		18	-0.064	-0.102	184.27	0.000
		19	-0.107	-0.010	185.21	0.000
		20	-0.154	-0.029	187.22	0.000

Appendix L4. CNY/EUR Autocorrelation Test at First Difference (2015.03-2018.12)

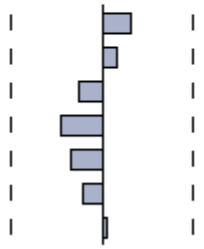
Date: 09/27/19 Time: 10:06
Sample: 2015M03 2018M12
Included observations: 45



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.201	-0.201	1.9494	0.163
		2	-0.073	-0.118	2.2086	0.331
		3	-0.149	-0.200	3.3320	0.343
		4	0.200	0.122	5.3892	0.250
		5	-0.246	-0.235	8.5918	0.126
		6	0.043	-0.049	8.6918	0.192
		7	-0.065	-0.090	8.9254	0.258
		8	0.037	-0.107	9.0031	0.342
		9	-0.067	-0.045	9.2639	0.413
		10	-0.075	-0.224	9.6052	0.476
		11	-0.066	-0.178	9.8784	0.541
		12	0.180	0.040	11.957	0.449
		13	0.039	-0.014	12.056	0.523
		14	0.003	0.018	12.057	0.602
		15	0.107	0.143	12.868	0.613
		16	0.064	0.073	13.170	0.660
		17	-0.002	0.156	13.170	0.725
		18	-0.073	0.048	13.592	0.755
		19	-0.048	-0.024	13.779	0.796
		20	-0.132	-0.113	15.248	0.762

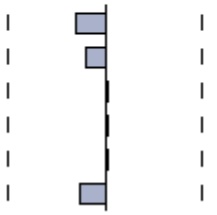
Appendix L5. Autocorrelation Test at Levels (2019.01-2019.08)

Date: 09/27/19 Time: 10:07
Sample: 2019M01 2019M08
Included observations: 8

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.224	0.224	0.5743	0.449
		2	0.120	0.074	0.7665	0.682
		3	-0.175	-0.229	1.2577	0.739
		4	-0.326	-0.279	3.3770	0.497
		5	-0.238	-0.092	4.8849	0.430
		6	-0.143	-0.048	5.7002	0.458
		7	0.037	0.012	5.8100	0.562

Appendix L6. Autocorrelation Test at First Difference (2019.01-2019.08)

Date: 09/27/19 Time: 10:08
Sample: 2019M01 2019M08
Included observations: 7

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.238	-0.238	0.5932	0.441
		2	-0.151	-0.220	0.8809	0.644
		3	0.020	-0.084	0.8874	0.828
		4	0.033	-0.020	0.9098	0.923
		5	0.026	0.025	0.9309	0.968
		6	-0.190	-0.189	3.2065	0.783

Appendix L7. CNY/EUR UIP Test (2009.10-2015.02)

Dependent Variable: LOG(CNY_EUR__T_3_)-LOG(CNY_EUR)
Method: Least Squares
Date: 09/27/19 Time: 11:38
Sample (adjusted): 2009M10 2015M02
Included observations: 65 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.006690	0.003352	-1.995614	0.0503
CNY_1Y-US_1Y_YIELD	0.002730	0.001204	2.268054	0.0268

R-squared	0.075488	Mean dependent var	0.000611
Adjusted R-squared	0.060813	S.D. dependent var	0.007785
S.E. of regression	0.007545	Akaike info criterion	-6.905645
Sum squared resid	0.003586	Schwarz criterion	-6.838740
Log likelihood	226.4335	Hannan-Quinn criter.	-6.879247
F-statistic	5.144067	Durbin-Watson stat	0.857360
Prob(F-statistic)	0.026764		

Appendix L8. CNY/EUR UIP Test (2015.03-2018.12)

Dependent Variable: LOG(FW_CNY_EUR)-LOG(CNY_EUR)
Method: Least Squares
Date: 09/27/19 Time: 11:46
Sample: 2015M03 2018M12
Included observations: 46

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.011869	0.002502	4.743467	0.0000
CNY_YIELD_1Y-US_YIELD_1Y	-0.000849	0.001427	-0.594675	0.5551

R-squared	0.007973	Mean dependent var	0.010495
Adjusted R-squared	-0.014573	S.D. dependent var	0.006482
S.E. of regression	0.006529	Akaike info criterion	-7.182739
Sum squared resid	0.001875	Schwarz criterion	-7.103233
Log likelihood	167.2030	Hannan-Quinn criter.	-7.152955
F-statistic	0.353638	Durbin-Watson stat	0.803838
Prob(F-statistic)	0.555107		

Appendix L9. CNY/EUR UIP Test (2019.01-2019.08)

Dependent Variable: LOG(FW_CNY_EUR)-LOG(CNY_EUR)
Method: Least Squares
Date: 09/27/19 Time: 12:05
Sample (adjusted): 2019M01 2019M08
Included observations: 8 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.009244	0.001332	6.938794	0.0004
CNY_1Y_YIELD-US_1Y_YIELD	-0.001429	0.002893	-0.494184	0.6387

R-squared	0.039111	Mean dependent var	0.008806
Adjusted R-squared	-0.121037	S.D. dependent var	0.002657
S.E. of regression	0.002813	Akaike info criterion	-8.696516
Sum squared resid	4.75E-05	Schwarz criterion	-8.676656
Log likelihood	36.78607	Hannan-Quinn criter.	-8.830467
F-statistic	0.244218	Durbin-Watson stat	1.904131
Prob(F-statistic)	0.638745		

Appendix. M1. US Currency Pairs Johansen Cointegration Test (2005.01-2008.10)

Date: 09/27/19 Time: 14:31
Sample (adjusted): 2005M03 2008M10
Included observations: 44 after adjustments
Trend assumption: Linear deterministic trend
Series: ZAR_USD RUB_USD INR_USD CNY_USD BRL_USD
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.424646	59.48396	69.81889	0.2515
At most 1	0.243092	35.16205	47.85613	0.4395
At most 2	0.237850	22.90744	29.79707	0.2506
At most 3	0.159463	10.95651	15.49471	0.2142
At most 4	0.072532	3.313057	3.841466	0.0687

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.424646	24.32191	33.87687	0.4323
At most 1	0.243092	12.25461	27.58434	0.9220
At most 2	0.237850	11.95094	21.13162	0.5525
At most 3	0.159463	7.643449	14.26460	0.4161
At most 4	0.072532	3.313057	3.841466	0.0687

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

ZAR_USD	RUB_USD	INR_USD	CNY_USD	BRL_USD
-2.149146	0.048843	0.430844	-9.068332	8.857845
-0.338121	0.734379	0.344981	-0.836435	-7.287476
-0.424400	0.120250	0.329806	1.877004	-2.202839
2.691949	0.232507	0.046424	-0.934614	4.003241
1.019732	2.140938	-0.497941	-6.741075	2.289643

Appendix M2. US Currency Pairs Johansen Cointegration Test (2008.11-2017.10)

Date: 09/27/19 Time: 14:30
Sample (adjusted): 2009M04 2017M10
Included observations: 103 after adjustments
Trend assumption: Linear deterministic trend
Series: BRL_USD CNY_USD INR_USD RUB_USD ZAR_USD
Lags interval (in first differences): 1 to 4

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.361133	93.10159	69.81889	0.0002
At most 1	0.203668	46.95153	47.85613	0.0607
At most 2	0.150802	23.49437	29.79707	0.2226
At most 3	0.039898	6.657695	15.49471	0.6177
At most 4	0.023638	2.463953	3.841466	0.1165

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.361133	46.15006	33.87687	0.0011
At most 1	0.203668	23.45715	27.58434	0.1548
At most 2	0.150802	16.83668	21.13162	0.1798
At most 3	0.039898	4.193742	14.26460	0.8384
At most 4	0.023638	2.463953	3.841466	0.1165

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

BRL_USD	CNY_USD	INR_USD	RUB_USD	ZAR_USD
-4.617789	-2.370929	-0.687855	-0.152519	3.939676
2.102550	-5.889091	-0.142436	0.073341	-0.361157
-8.883248	-0.642040	0.019586	0.244529	0.805227
0.513238	-0.124065	-0.209602	0.127004	-0.119439
-2.094682	2.184616	0.149186	0.024783	0.391546

Appendix M3. U.S. Currency Pairs Johansen Cointegration Test (2017.11-2019.08)

Date: 09/27/19 Time: 14:27
Sample (adjusted): 2018M01 2019M08
Included observations: 20 after adjustments
Trend assumption: Linear deterministic trend
Series: ZAR_USD RUB_USD INR_USD CNY_USD BRL_USD
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.848124	101.5463	69.81889	0.0000
At most 1 *	0.790582	63.85252	47.85613	0.0008
At most 2 *	0.640293	32.58403	29.79707	0.0233
At most 3	0.363103	12.13469	15.49471	0.1506
At most 4	0.144088	3.111744	3.841466	0.0777

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.848124	37.69382	33.87687	0.0167
At most 1 *	0.790582	31.26850	27.58434	0.0160
At most 2	0.640293	20.44933	21.13162	0.0621
At most 3	0.363103	9.022951	14.26460	0.2842
At most 4	0.144088	3.111744	3.841466	0.0777

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

ZAR_USD	RUB_USD	INR_USD	CNY_USD	BRL_USD
-1.326896	-0.543780	1.134430	-3.418415	5.406937
2.452571	0.394618	0.238948	-0.596955	-17.37433
-0.070262	0.569776	-0.210246	-0.519236	-1.762111
4.166506	-0.398127	0.251578	-16.37218	3.466957
-0.035734	0.420249	-0.216169	-11.24137	3.577904

Appendix N1. E.U. Currency Pairs Cointegration Test (2005.01-2015.02)

Date: 09/27/19 Time: 14:48
Sample (adjusted): 2005M06 2015M02
Included observations: 117 after adjustments
Trend assumption: Linear deterministic trend
Series: BRL_EUR CNY_EUR INR_EUR RUB_EUR ZAR_EUR
Lags interval (in first differences): 1 to 4

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.293068	84.29092	69.81889	0.0023
At most 1	0.166044	43.71290	47.85613	0.1161
At most 2	0.106356	22.46861	29.79707	0.2732
At most 3	0.057960	9.312224	15.49471	0.3373
At most 4	0.019688	2.326434	3.841466	0.1272

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.293068	40.57802	33.87687	0.0069
At most 1	0.166044	21.24429	27.58434	0.2617
At most 2	0.106356	13.15639	21.13162	0.4380
At most 3	0.057960	6.985790	14.26460	0.4908
At most 4	0.019688	2.326434	3.841466	0.1272

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

BRL_EUR	CNY_EUR	INR_EUR	RUB_EUR	ZAR_EUR
1.952424	-2.020275	-0.499751	0.126173	1.308710
4.726474	0.557061	-0.165432	0.446451	-0.344698
1.177006	-0.093964	-0.020296	-0.083197	0.690712
-2.437037	0.741015	-0.159954	0.282824	0.620928
-0.117359	0.573354	0.017850	-0.282546	0.362401

Appendix N2. E.U. Currency Pairs Cointegration Test (2015.03-2018.12)

Date: 09/27/19 Time: 14:49
Sample (adjusted): 2015M05 2018M12
Included observations: 44 after adjustments
Trend assumption: Linear deterministic trend
Series: BRL_EUR CNY_EUR INR_EUR RUB_EUR ZAR_EUR
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.551694	75.99890	69.81889	0.0148
At most 1	0.362281	40.69860	47.85613	0.1985
At most 2	0.259853	20.90484	29.79707	0.3636
At most 3	0.126674	7.664953	15.49471	0.5019
At most 4	0.038016	1.705305	3.841466	0.1916

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.551694	35.30030	33.87687	0.0336
At most 1	0.362281	19.79376	27.58434	0.3556
At most 2	0.259853	13.23989	21.13162	0.4304
At most 3	0.126674	5.959647	14.26460	0.6184
At most 4	0.038016	1.705305	3.841466	0.1916

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

BRL_EUR	CNY_EUR	INR_EUR	RUB_EUR	ZAR_EUR
2.666233	-2.621536	0.249870	-0.477536	1.032897
-1.004961	0.914189	0.002644	0.274562	-1.952931
-5.339136	-3.939071	0.669839	-0.093634	0.979260
0.281167	4.331084	-0.361193	-0.026968	-0.086980
-1.428693	-1.916341	-0.060880	0.011052	0.295692

Appendix N3. E.U. Currency Pairs Cointegration Test (2019.01-2019.08)

Date: 09/27/19 Time: 14:57
Series: ZAR_EUR RUB_EUR INR_EUR CNY_EUR BRL_EUR
Sample: 2019M01 2019M08
Included observations: 8
Null hypothesis: Series are not cointegrated
Cointegrating equation deterministics: C
Automatic lags specification based on Schwarz criterion (maxlag=1)

Dependent	tau-statistic	Prob.*	z-statistic	Prob.*
ZAR_EUR	-4.952535	0.1850	-10.27411	0.9994
RUB_EUR	-7.415873	0.0295	-12.32021	0.9982
INR_EUR	-7.606918	0.0255	-12.57432	0.9982
CNY_EUR	-3.640636	0.4636	-9.497743	0.9474
BRL_EUR	-3.820518	0.4117	-9.896625	0.9906

*MacKinnon (1996) p-values.
Warning: p-values may not be accurate for fewer than 20 observations.

Intermediate Results:

	ZAR_EUR	RUB_EUR	INR_EUR	CNY_EUR	BRL_EUR
Rho - 1	-1.467730	-1.760029	-1.796332	-1.356820	-1.413804
Rho S.E.	0.296359	0.237333	0.236145	0.372688	0.370055
Residual variance	0.013925	0.097325	0.083191	0.004870	0.002341
Long-run residual variance	0.013925	0.097325	0.083191	0.004870	0.002341
Number of lags	0	0	0	0	0
Number of observations	7	7	7	7	7
Number of stochastic trends**	5	5	5	5	5

**Number of stochastic trends in asymptotic distribution