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Regime Switching, Exchange Rate Volatility and Intervention in BRICS Currency Markets

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Abstract: Empirical evidence on foreign exchange markets in emerging market economies show changing volatility patterns. Using a univariate Markov regime switching model on daily data between April 2006 and March 2018 and, this paper analyses the changes in volatility pattern in BRICS foreign currency markets. The smoothed probability curves identify the phases of volatility during the period. Chinese Yuan is found to be the least volatile across regimes among BRICS currencies, whereas it is the highest for South African Rand. Such lower volatility in China's currency follows from higher intervention in the currency market by The People's Bank of China.

JEL Classification: C34, C58, E44, F31, G15

Key Words: Exchange Rate, Markov Regime Switching, Volatility, Exchange Market Pressure, Intervention Index, Market Synchronization, BRICS

Introduction

With exchange rates being found to fluctuate inadvertently, understanding its behaviour has been a major task for both academic and policy research. Global turnover in foreign exchange market in the recent period is much higher than earlier and it is not the result of international trade alone, but can be on account of speculation and market trading activities in the foreign exchange market BIS (2016). With increasing flexibility of the exchange rate regime in the emerging market economies (EME's),

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the volatility in the respective foreign currency markets of EME's has increased manifold (Kocenda and Valachy 2006) and the monetary authorities intervene at times to counter the volatility (Dooley 2000, Chang and Velasco 1998 and Cespedes et al. 2004).[1] One of the most influential papers of the genre of literature on exchange rate management is Krugman (1991).[2] Post global financial crisis of 2008, the Basel III norms introduced more enhanced risk management mechanism in the banking system to counter persistent exchange rate volatility that can result into a crisis. Managing and predicting currency volatility is a major policy target for individual central banks while formulating monetary policy in emerging market economies, including Brazil, Russia, India, China and South Africa – the BRICS economies.

Predicting the behaviour of exchange rates and modelling it is a challenge for the economists since Meese and Rogoff (1983a,b) opined that fundamentals-based exchange rate models cannot forecast exchange rate changes for less than a year. The Markov Switching model by Engel and Hamilton (1990) became important with several studies fail to quash the findings of Meese and Rogoff.[3] Engel and Hamilton (1990) suggest that Markov switching model provides a framework in which regimes are characterized by a combination of lower and higher mean and volatility and developed a new statistical model of exchange rate dynamics, which when employed, showed long-swing in Dollar and outperformed the random walk model. The use of Markov switching model merges two different strands of literature: the first strand uses ARIMA models to forecast out of sample exchange rates (Neely et al. 1997) while the second strand attempts to forecast exchange rates using Markov switching models of lower frequency (Engel and Hamilton 1990, Engel 1994). The main purpose of this regime switching stochastic models is to take into account the important aspects of the data such as mean trend gap that can be observed at different points of time. Further, there are large variations in the foreign exchange market which results in pressure in currency markets, thereby often requiring intervention by respective central banks.

A study on the BRICS currencies is crucial as these have emerged important in the global economy (Huidrom et al. 2016). According to the Bank for International Settlements Triennial Central Bank Survey (2016), the foreign exchange market turnover was $51 Billion for Brazil, $58 Billion for Russia, $58 billion for India, $202 billion for China and $49 billion for South Africa respectively, thereby contributing almost 8.25 per cent of the total foreign exchange turnover in the world. However, these currencies have witnessed large movements during the period of study. Standard deviation for these currencies during the period are 0.010 (Brazilian Real), 0.009 (Russian Ruble), 0.005 (Indian Rupee), 0.001 (Chinese Yuan) and 0.011 (South African Rand). Thus, in order to contain excess volatility, the BRICS economies have intervened in the respective currency markets through purchase and sale of foreign currencies. For instance, the central bank of Brazil, Russia, India and South Africa conducted the sale of foreign exchange during the global financial crisis in 2008. According to Federal Reserve Bank of St. Louis database, the forex reserves for Brazil fell from US$ 205.54 billion in September 2008 to US$ 187.10 billion in January 2009, from US$ 542.84 billion in September 2008 to US$ 371.43 billion in January 2009 for Russian Ruble, from US$ 277.77 billion in September 2008 to US$ 239.69 billion in January 2009 for India and from US$ 308.32 billion in September 2008 to US$ 300.09 billion in January 2009 for South Africa which indicate sale of foreign exchange reserves. On the other hand, China purchased foreign exchange during the global financial crisis in 2008, as its reserves increased from US$ 190.77 billion to US$ 191.66 billion particularly between September 2008 and January 2009.

Given the growing importance of BRICS in the world economy, the study attempts to examine the pattern of regime switching behaviour and volatility in the BRICS foreign exchange markets using a Markov switching autoregressive model. In addition, it examines the Exchange Market Pressure to characterize the pressure on each currency to appreciate or depreciate and thereafter the intervention in the currency market, as shown by the intervention index, conducted by the respective

central banks to contain such exchange market pressure. This exercise also formulates the portfolio diversification strategies by examining the market synchronization properties of the sample foreign currency markets. These three aspects, which are being dealt with in this paper, will provide a possible direction to concerned policy makers to manage the respective foreign exchange markets in case of any misalignment. The structure of the paper is as follows: Section 2 provides with a review of the existing literature on the subject and section 3 delineates the econometric methodology and the data used in the study. Section 4 presents the empirical results. Section 5 concludes with summary of major findings and policy implications.

2. Review of literature

Often volatility is found to switch from low to high and vice versa, thereby leading to regime shifts. Regime shifts are essentially captured in the literature using regime switching models, Markov switching model is one such model. The Markov switching model (MSM), introduced by Goldfeld and Quandt (1973), captures discrete shift in the data generating process in a time series [Hamilton (1988, 1989)]. Engle and Hamilton (1990) view that MSMs to be a good approximation to the underlying processes, as well as having excellent predictive power of nonlinearities time series (Hamilton 1994). Since then a substantial literature on regime-switching models has emerged, covering theoretical extensions as well as empirical applications to economic and financial variables such as inflation rates, stock returns, aggregate output levels and interest rates.[4]

Regime-switching in exchange rate, both nominal and real, has been documented by Bekaert and Hodrick (1993), Engel and Hakkio (1996) and more recently by Bergman and Hansson (2005) and Lee and Chen (2006). These papers mainly provide empirical evidence that regime-switching models typically outperform single regime exchange rate models. Further, many researchers use the regime switching models in the estimation and forecasting of exchange rate and advocated that these models fit exchange rate data well and generate better forecasts

as compared to any random walk model or other models (Nikolsko-Rzhevskyy and Prodan 2012). Some authors thus advocate the use of regime-switching models in financial applications including the valuation of currency options (Bollen et al. 2000).[5]

Engel (1994) fits the Markov-switching model for 7 USD and 11 non-USD exchange rate series and finds that the model fits well in-sample for many exchange rates, but is not able to generate forecasts which are superior to the random walk according to either the Mean Square Prediction Error (MSPE) or mean absolute error (MAE) criteria. Klaassen (2005) enhances Engel's model with a GARCH error structure, but fails to find any nominal exchange rate predictability based on the MSPE criterion. Goutte and Zou (2013) compare the results given by the good fit of different regime switching models against non regime switching diffusion on foreign exchange rate data and proved that regime switching models with both mean reverting and local volatility structures fit the data well. Moreover, this modelling allows them to capture crisis time periods or change in the dynamic level of variance. Marsh (2000) adds the fundamental factor to the model, uses interest rates to investigate the daily variation of exchange rates. Dewachter (2001) extends the MSM by introducing separate and independent latent variables for the dynamics in mean and variance. The applications of the MSM capture some major dynamics that characterize exchange rate behaviour, although the structure may vary over time. Caporale and Spagnolo (2004) showed that the behaviour of East Asian exchange rates is nonlinear. Frommel, MacDonald, and Menkhoff (2005a, 2005b) find that the factors that were closely related to regime switches were short-term interest rates, inflation differentials and differences in economic growth.

With regards to currencies, such as German Mark, Euro, Yen, British Pound and Swiss Franc, Dueker and Neely (2007) find that Markov model generates significant and more stable out of sample excess returns. Evans and Lewis (1995) assume that the exchange rate switches between appreciating and depreciating regimes, which are incorporated into rational traders' forecasts of the future exchange rate. Shen and Chen

(2004) show that developed countries experience symmetric swings in exchange rates, while developing countries may experience asymmetric adjustment speeds.

This regime switching appreciation or depreciation in the foreign exchange markets, often referred to as Exchange Market Pressure (EMP), occurs because of some shocks originating during the crisis periods or because of speculative or trading activity by the policy authorities or investors, among other factors. The exercise on exchange market pressure leads to an important understanding of exchange rate management in terms of the volume of intervention necessary to achieve any desired exchange rate target. For instance, Girton and Roper (1977) employs a model on postwar Canadian economy to explain both exchange rate movements and official intervention and show that exchange market pressure provide a measure of the volume of intervention necessary to achieve any desired exchange rate target. Weymark (1995), using quarterly bilateral and multilateral estimates of exchange market pressure and the degree of exchange market intervention for Canada, shows that the Bank of Canada was engaged in exchange rate management and suggests that the bilateral Canadian Dollar-U.S. Dollar exchange rate was the prime target of these intervention activities. Kumah (2011) identified episodes of Exchange Market Pressure (EMP) in the Kyrgyz Republic in a three regime MSM and confirm the statistical superiority of the nonlinear regime-switching model over a linear VAR in understanding EMP.

These papers provide an insight into the exchange rate movements that was modelled in a Markov switching framework and thereafter the degree of intervention, primarily shown by the intervention index, being conducted by the respective central banks to stabilize the currency. It is important to mention here that there are few studies which have looked into the aspect of Exchange Market Pressure and there are even fewer studies which have dealt both with Markov Switching Model and Exchange Market Pressure simultaneously. Fiess and Shankar (2009), an exception in this regard, show that the exchange rate policy of the central banks primarily depends on the financial and economic fundamentals.

Using monetary model, the paper derives a policy reaction function for the central bank for fifteen countries where the disequilibrium in the money market disequilibrium and the consequent Exchange Market Pressure (EMP) can be neutralized by intervening, directly or indirectly, in the foreign exchange market. Moreover, to identify the shifts in the exchange market intervention, the study estimates a two state Markov switching autoregressive model with regime shifts in the mean of policy response indices and shows that policy regimes are mainly driven by country-specific constraints.

The entire range of literature reviewed above gives an idea about the performance of foreign exchange market during bear and bull regime. The preceding section not only provides an overview of using regime switching model in foreign currency markets in understanding market behavior and identifying volatility regimes but also detailed out the process of modelling exchange market pressure and the extent of intervention in foreign currency markets. However, the literature on regime switching – from bear to bull and/or vice versa – in foreign currency markets is less relative to other asset markets and that too in emerging markets including BRICS countries. This paper attempts to classify the mean return and volatility in the BRICS foreign exchange market by modelling a two state Markov Switching process. The paper also analyses exchange market pressure and constructs an intervention index which mainly reflects the level of intervention that is carried out by the central banks in case of any instability in the foreign exchange market mainly caused by either internal or external shock or both.

The Data and the Methodology

The Data

The study is carried out for the period April 2006[6] to March 2018 using daily exchange rate of Brazilian Real, Russian Ruble, Indian Rupee, Chinese Yuan and South African Rand (BRICS). The exchanges rate series were obtained from Bloomberg database.

The Methodology

In this sub-section the Markov Switching-Autoregressive model is discussed. Regarding the regime switching analysis, Quandt (1972) constructs the switching model where the state variable is an *iid* random sequence. In another paper, Goldfeld and Quandt (1973) propose a switching regression model with state variable as a two-state hidden Markov chain process. Hamilton (1989, 1990) extend the Goldfeld and Quandt (1973) model by allowing for regime shifts.

The estimation model used here is based on Hamilton (1989), which proposes that a time-series variable y_t can be modeled by a Markov switching autoregressive of order k with regime switching-in mean and variance which is as follows,

$$y_t = \mu(S_t) + \sum_{i=1}^{k} \varphi_i \left(y_{t-i} - \pi(S_{t-i})\right) + \sigma^2(S_t)\,\varepsilon_t \quad \text{.....(1)}$$

where y_t is the BRICS foreign exchange market return, μ is the mean and σ^2 is the variance depending on the regime S_t at time t, φ_i is the autoregressive coefficient, S_t and S_{t-i} are the unobserved states which takes the value 1 or 2 and the transition probabilities p_{ij} between the states are as follows:

$$p_{ij} = \Pr(S_t = j | S_{t-1} = i) \text{ with } \sum_{j=1}^{2} p_{ij} = 1 \text{ for all } i, j \in [1,2] \quad \text{....(2)}$$

where,

$$\left.\begin{array}{l} Prob(S_t = 1 | S_{t-1} = 1) = P_{11} \\ Prob(S_t = 1 | S_{t-1} = 2) = 1 - P_{11} \\ Prob(S_t = 2 | S_{t-1} = 2) = P_{22} \\ Prob(S_t = 2 | S_{t-1} = 1) = 1 - P_{22} \end{array}\right\} \quad \text{.....(3)}$$

where P_{11} is the probability of being in regime 1 given the system was in regime 1 in the previous period, P_{22} is the probability of being in regime 2 given that the system was in regime 2 in the previous period. The transition regime, 1-P_{11} is the probability that S_t will shift to state 1 in period t from state 2 in period t-1 and 1-P_{22} is the probability that S_t will shift to state 2 in period t from state 1 in period *t-1*. Nonetheless, the state dependent mean and

variances are described following Wang and Theobald (2008) as:

$$\mu_{(S_t)} = \mu_t S_{1t} + \ldots + \mu_{m1} S_{mt} \quad \ldots\ldots(4)$$

$$\sigma^2{}_{(S_t)} = \sigma_1^2 S_{1t} + \ldots + \sigma_{m1}^2 S_{mt} \quad \ldots\ldots(5)$$

where S_{mt} takes the value 1 when S_t is equal to m and 2 otherwise (Kim and Nelson). The Markov Switching model assumes that ε_t and S_t are independent, as shown in equations 1, 4 and 5, implying that the change in regime does not depend on past history. The parameters of Markov switching model is estimated by maximum likelihood which is performed using the EM algorithm as described by Hamilton (1989, 1990)[7].

In order to estimate the Exchange Market Pressure (EMP)[8] and the Intervention Index, a small open economy model specification is used[9] where purchasing power parity does not hold and the foreign prices and exchange rate influence the domestic prices. Moreover the uncovered interest parity links the foreign and the domestic interest rates. The model also assumes that domestic and foreign assets are perfect substitutes and that the domestic output and foreign prices are exogenous. Besides the domestic residents holds domestic currency for transaction and speculative purposes.

It is a well known fact that the central bank of any country formulates the exchange rate policy and intervenes in the foreign exchange market time to time to maintain the value of the domestic currency whenever there is an exchange rate pressure. According to Fiess and Shankar (2009), this EMP can be dealt in three possible manners: i) by adjusting the exchange rate; ii) by adjusting the interest rate; and iii) by direct or indirect intervention in the foreign exchange market. For instance, if the central bank involves in unsterilized intervention then EMP is defined as,

$$EMP_t = \Delta e_t + \eta \Delta r_t \quad \ldots\ldots(6)$$

where Δe_t is the change in exchange rate, Δr_t is the change in foreign exchange reserves and $\eta = -(\partial \Delta e_t / \partial \Delta r_t$ is the elasticity which converts

changes in reserves into equivalent units of exchange rate changes. Whenever the central bank intervenes, the movement of exchange rate and foreign exchange reserves is in contradiction to each other. To measure the degree of intervention in the foreign exchange market in case of any EMP, the following intervention index is used as defined by Weymark (1995),

$$\omega_t = \frac{\eta \Delta r_t}{EMP} \qquad \text{.....(7)}$$

However, equation (7) is modified following Kaminsky and Reinhart (1999) by setting η equal to the ratio of the standard deviation of the rate of change of exchange rate and standard deviation of the rate of change of foreign exchange reserves, i.e. $\eta = \sigma_{\Delta e_t} / \sigma_{\Delta r_t}$. Thus equation. 7) can be written as,

$$\omega_t = \frac{(\sigma_{\Delta e_t} / \sigma_{\Delta r_t})(\Delta r_t)}{(\sigma_{\Delta e_t} / \sigma_{\Delta r_t})(\Delta r_t) + \Delta e_t} \qquad \text{.....(8)}$$

Moreover the market synchronization analysis in the later part of the study explores the association among the currency markets by measuring the unconditional correlation between the logits of the smoothed probabilities of the bull and bear regimes of the respective BRICS markets.

Empirical Results

The analysis in this section is set out with the estimation of two-regime Markov switching model to identify regime specific mean and volatility of the BRICS foreign exchange markets. This is followed by the estimation of Exchange Market Pressure and Intervention Index to bring out the various phases of large appreciation and depreciation in the foreign exchange markets and the intervention by the respective central banks of individual BRICS countries to contain large changes in the respective currency value. Prior to an econometric analysis of identifying the phases of volatility, it is important to have an understanding of the patterns of changes in the individual currency series.

The time pattern of BRICS currency daily returns series show wide fluctuations, as evident in Figure 1 and Table 1. The figure shows that the return of Brazilian Real is highest during 2008, 2011, 2015 and 2017, the return of Russian Ruble is highest during 2014, 2015 and 2016, the return of Indian Rupee is highest during 2009, 2010, 2012 and 2013, the return of Chinese Yuan is highest during 2016, 2017 and 2018 and the return of South African Rand is highest during 2008, 2011 and 2015. On the other hand, volatility seems to be clustered during 2008, 2009, 2015 and 2016 for Brazilian Real, Russian Ruble, Chinese Yuan and South African Rand whereas in case of Indian Rupee, the volatility clustering occurs during 2008, 2009 and 2011-2013. Thus it can be inferred from the statistics above, that in most of the cases, the return series exhibits high return with high volatility and vice-versa during the same period which is further corroborated with the findings of Markov Switching analysis.

Table 1 further reports the descriptive statistics of the returns series[10] of Brazilian Real, Russian Ruble, Indian Rupee, Chinese Yuan and South African Rand for the period 2006-2018. It is evident from the table that the mean return is highest for Russian Ruble which is followed by South African Rand, Brazilian Real, Indian Rupee and Chinese Yuan, with negative mean return for the last two currencies. Moreover, the variations in the returns of currencies, as measured by standard deviation, is the highest for South African Rand followed by those of Brazilian Real, Russian Ruble, Indian Rupee and Chinese Yuan. Hence, it can be observed from the table that Chinese Yuan has low return with low volatility among other BRICS currencies. It is also interesting to note that the variations in returns for the Chinese Yuan and Indian Rupee is lower among the currencies of other BRICS countries which is possibly an indication of significant interventions by the respective central banks.

Figure 1: Time Pattern of BRICS exchange rate return

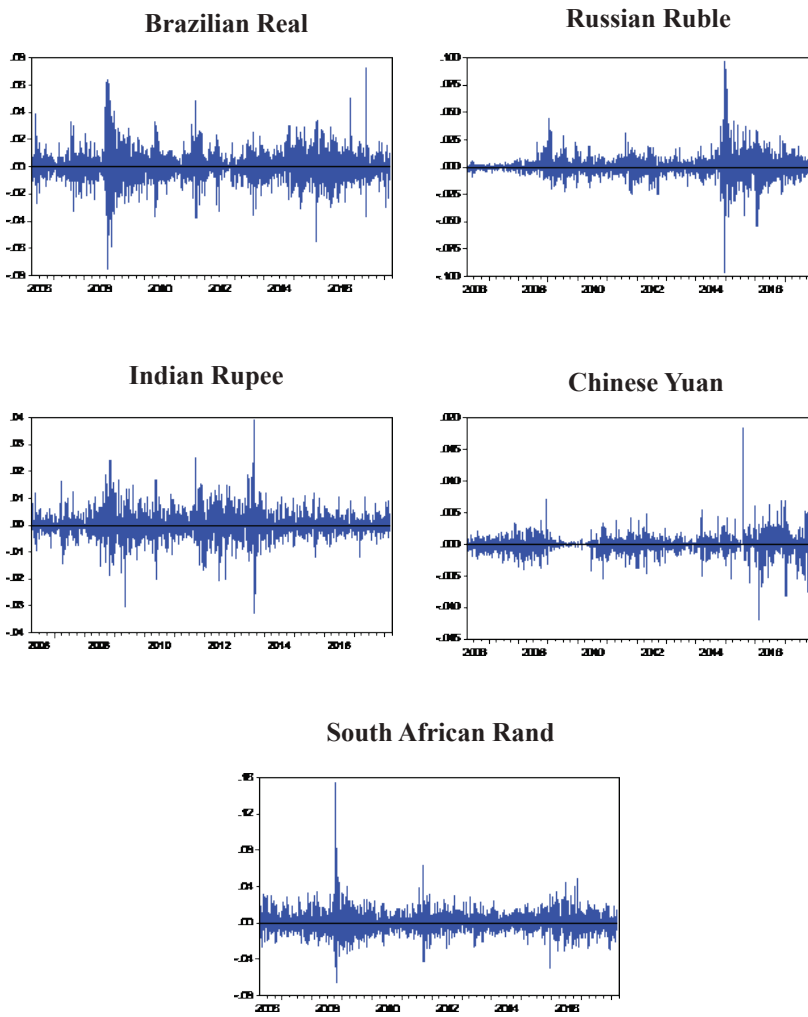


Table 1: Descriptive Statistics: Return series of currencies in BRICS countries

	Brazilian Real	Russian Ruble	Indian Rupee	Chinese Yuan	South African Rand
Mean	0.00007	0.00037	-0.00016	-0.00007	0.00022
Standard Deviation	0.010426	0.008919	0.004736	0.001343	0.01093
Obs.	4381	4381	4381	4381	4381

Finally, the descriptive statistics and the figure on the time path of all the return series exhibit volatility and also reveal volatility clustering during the entire sample period. This finding is possibly suggestive of the fact that the individual currency markets were turbulent for a large part of the sample period, either by account of some external shocks or domestic shocks arising on account of the change in some policy variables by the concerned authorities or following the spillover effect of some crises that originated during the period of study. Econometric estimations that follow identify the phases of such fluctuations observed and the extent of interventions by respective central banks to contain wide changes.

Markov Switching Analysis

The univariate Markov switching analysis of the BRICS foreign exchange markets is looked into using the two-state regime switching behaviour of the respective currency markets, the two states being bullish and bearish. From table 2, it can be noted that the BRICS currency returns are negative in regime 1 and positive in regime 2, except for Chinese Yuan. Regime 1 can thus be characterized as bearish and regime 2 as bullish which is in conformity with the literature on Markov Switching model. The transition regimes of shifting from regime 1 to regime 2 and vice-versa is arrived at by using equation (3). Among the BRICS currency markets, as evident from Table 2, the highest return during the bearish regime (μ_1) is observed in case of Chinese Yuan followed by Russian Ruble, South African Rand, Brazilian Real and Indian Rupee whereas the highest return during the bullish regime (μ_2) is found in case of South African Rand followed by Russian Ruble, Brazilian Real, Indian Rupee

and Chinese Yuan. Besides, the highest volatility in both regime 1 (σ_1) and regime 2 (σ_2) is in case of South African Rand followed by Brazilian Real, Russian Ruble, Indian Rupee and Chinese Yuan. It is important to note here that, in most BRICS currency markets, the bearish regime has lower mean and volatility as compared to that in a bullish regime. The table also reveals that Chinese Yuan, among others, has the highest return and low volatility during the bearish regime. However, the Indian Rupee has low return with low volatility. On the other hand, during the bullish regime, South African Rand has the highest return with highest volatility and on the contrary, Chinese Yuan has the lowest return with lowest volatility. Given the scenario, Chinese Yuan can be considered as the most attractive currency as it is less volatile in both the regimes although the mean return varies across regimes. The South African Rand, on the other hand, is least attractive among the BRICS currencies given its volatility in both the regimes.

With regards to the duration of stay (in days) of the foreign exchange markets in each regimes, it can be observed from Table 2 that Russian Ruble has the highest persistence during the bearish regime followed by Brazilian Real, South African Rand and similar for Indian Rupee and Chinese Yuan. During the bullish regime, persistence is higher also for Russian Ruble, Brazilian Real, Indian Rupee although it is same for Chinese Yuan and South African Rand. The duration of stay, considering both the bear and bull regimes, is the longest for Russian Ruble followed by Brazilian Real, South African Rand, Indian Rupee and Chinese Yuan.

The smoothed probability curves shown in Figure 2 for the bearish and bullish regime also support the above findings. The graphs give a clear indication of the probability of occurrence of bearish and bullish regimes and are representative of the fact that the currency markets are affected by crises such the global financial crisis starting in 2007 and finally occurring in 2008, the Eurozone debt crisis in 2011, the Russian financial crisis in 2014 or the deep plunge in oil price during mid-2014 to 2016.

A detailed computation of the bear and bull regime cycle of the BRICS currency markets from the smoothed probabilities show that Chinese Yuan has the highest number of cycles (110) followed by Indian Rupee (93), South African Rand (61), Brazilian Real (55) and Russian Ruble (45) respectively[11]. The persistence of the overall cycle is uniformly higher for bear regime as compared to the bull regime. The longest overall cycle (bear regime and bull regime) occurs in case of Russian Ruble in cycle 3 (04/04//2006 to 11/08/2008) for 860 days. Chinese Yuan follows the Russian currency in this regard where the overall cycle occurs in cycle 33 (05/02/2009 to 03/07/2010) for 509 days. The longest overall cycle for Brazilian Real in cycle 3 (08/07/2006 to 29/08/2007) is 405 days, South African Rand in cycle 40 (07/02/2014 to 08/02/2015) for 354 days, and Indian Rupee in cycle 4 (07/06/2006 to 16/11/2006) for 148 days. The dates, indicating the longest duration of Brazilian Real, Russian Ruble, Chinese Yuan and Indian Rupee suggests that they are probably affected by the onset or aftermath of global financial crisis whereas the South African Rand is probably affected by the deep plunge in oil price. It is noteworthy that the duration of the longest overall cycle for the Russian Ruble, Chinese Yuan and Brazilian Real is more than a year and it close to a year for South African Rand. In contrast, it is less than half a year for the Indian Rupee.

Table 2: Estimates of Univariate Markov Switching Model

	Brazilian Real	Russian Ruble	Indian Rupee	Chinese Yuan	South African Rand
μ_1	-0.000218	-0.000091	-0.000318*	-0.000029	-0.000207
μ_2	0.000700**	0.001267**	0.000242**	-0.000161	0.001519
σ_1	0.005704*	0.003848*	0.002098*	0.000486*	0.007101*
σ_1	0.015916*	0.013904*	0.006483*	0.001988*	0.016864*
φ	0.254304*	0.317691*	0.361041*	0.312755*	0.274858*
P_{11}	0.966572	0.947617	0.928706	0.932113	0.962403
1-P_{11}	0.033428	0.052383	0.071294	0.067887	0.037597
P_{22}	0.928400	0.975078	0.894676	0.889692	0.893308
1-P_{22}	0.071600	0.024922	0.105324	0.110308	0.106692

Table 2 continued...

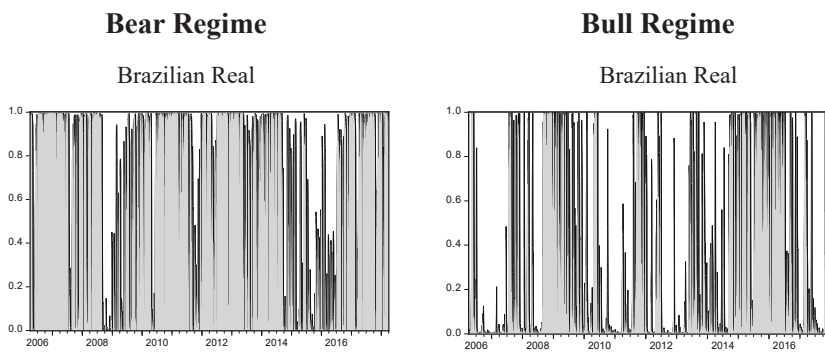
Table 2 continued...

Duration 1	30	40	14	14	27
Duration 2	14	19	10	9	9
Log Likelihood	14633.73	15978.06	18270.46	24231.18	14150.83
AIC	-6.678871	-7.292722	-8.339480	-11.06127	-6.458368

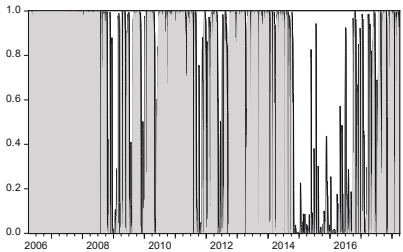
Note: * and ** denote significance at 1% and 5% level

The existence of such cycles also shows the periods when these currencies have gone through large appreciation or depreciation, normally referred to as Exchange Market Pressure, on account of some shocks originating within or outside the country or because the investors are willing to change their portfolio to developed countries or to the BRICS countries depending on the prevailing market conditions. In response to such Exchange Market Pressure, the central bank often opts to intervene in the foreign exchange market to stabilize the value of the domestic currency and to maintain overall stability of the economy. The next section details out the estimation of Exchange Market Pressure that occurred in the BRICS foreign exchange markets during the sample period and thereafter the intervention that were conducted by the respective central banks to maintain peace and tranquility in the foreign exchange market.

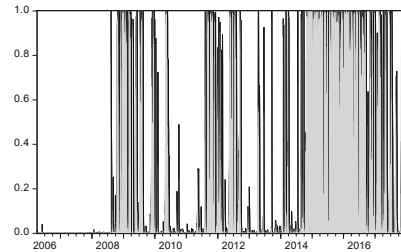
Figure 2: Smoothed Probability Curve



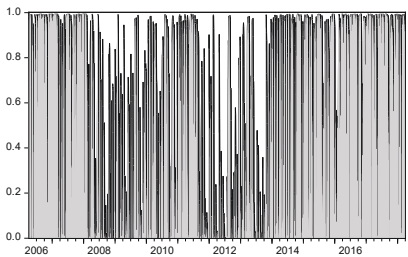
Russian Ruble



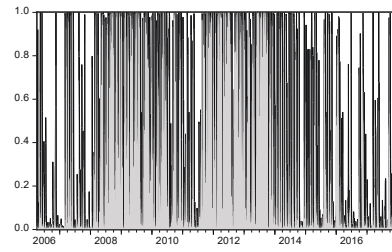
Russian Ruble



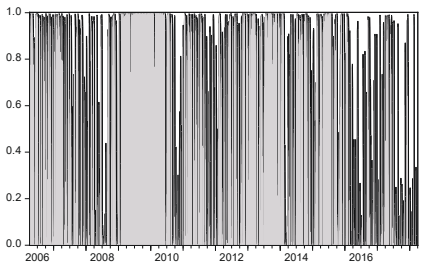
Indian Rupee



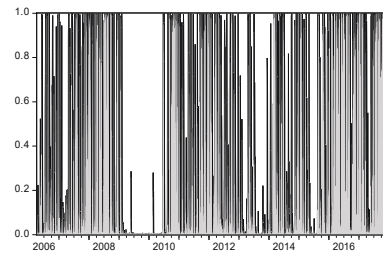
Indian Rupee



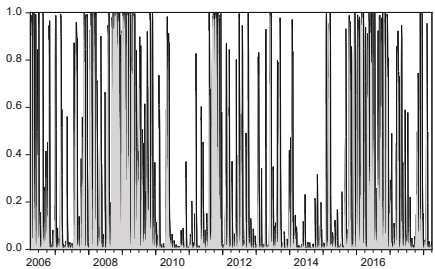
Chinese Yuan



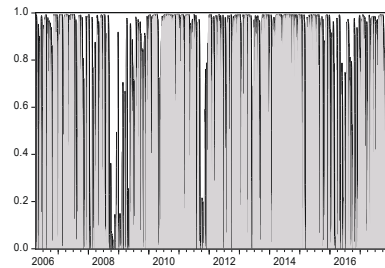
Chinese Yuan



South African Rand



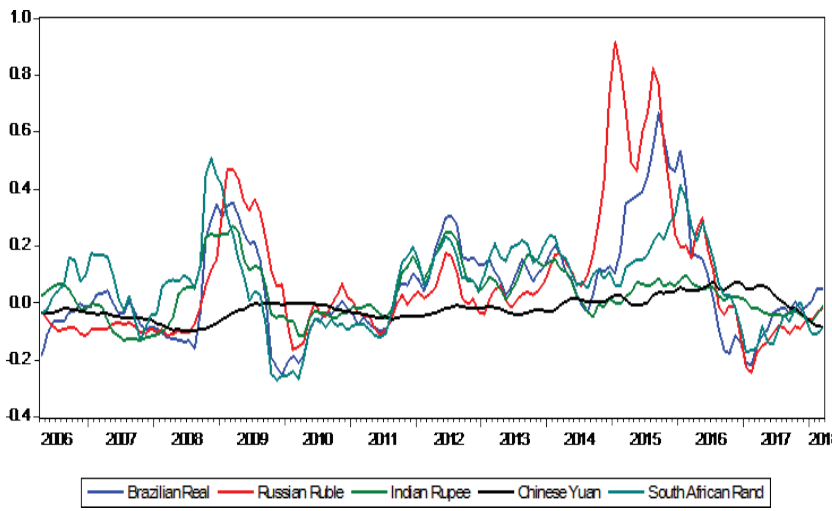
South African Rand



4.2 Exchange Market Pressure and Intervention Index: BRICS Foreign Exchange Market

The estimates of the Exchange Market Pressure (EMP) and the Intervention Index show the phases of appreciation and depreciation in the BRICS foreign exchange markets and thereafter the degree of intervention that is conducted by the central banks to stabilize the currency market. The Figure 3 below depicts the EMP of BRICS currency markets. It can observed from the figure that Brazilian Real, Russian Ruble, Indian Rupee and South African Rand had a depreciating phase during 2008-09, 2011-12, 2013-14 and in 2015-16. On the other hand, the Chinese Yuan started depreciating only after 2014 and peaked in 2016, indicating thorough intervention by the monetary authorities. These depreciating phases corresponds with the global financial crisis in 2008-09, the Eurozone Debt crisis in 2011-12, the Russian Financial crisis during 2014-17 or the deep plunge in oil price during mid-2014 to 2016.

Figure 3: Exchange Market Pressure of BRICS Nations



The large positive estimates obtained during these periods point to the fact that these currencies were subjected to speculative attacks because of the occurrence of these crises. Contrary to this, is the negative estimate which signifies the appreciation of these currencies over that particular period. It is also important to note here that the phases of downward pressure are more prominent for Brazilian Real, Russian Ruble, Indian Rupee and South African Rand as compared to Chinese Yuan. This prompted the monetary authorities of the respective countries to intervene and restore equilibrium in the foreign exchange markets.

The intervention index, as evident from Figure B1 (Appendix) reveals the extent of intervention in the foreign currency market by the respective central banks. It can observed from Figure B1 (Appendix) that the respective central banks intervened during 2008-09, 2011-12, 2013-14 and in 2015-16 to counter the depreciation of the currency. The estimated values more than 1 are much higher for South African Rand followed by Indian Rupee, Russian Ruble, Brazilian Real and Chinese Yuan. This is suggestive of the fact that the central bank of China conducts a more protective foreign exchange market intervention with respect to US Dollars to restore the value of its currency in case of any EMP which is further followed by Brazilian Real, Russian Ruble, Indian Rupee and South African Rand. This corroborates with our finding in the Figure 3. Moreover the mean value of the intervention index[12] is 1.044614, 1.080173, 1.035942, 0.983801 and 1.071473 for Brazilian Real, Russian Ruble, Indian rupee, Chinese Yuan and South African Rand respectively. These mean values suggest that whenever the central banks of Brazil, Russia, India and South Africa attempt an intervention to defend any kind of depreciation of the domestic currency, it resulted in an appreciation of the bilateral exchange rate. The case with Chinese Yuan is slightly different. The mean value of the intervention index for the Chinese Yuan is 0.983801, which is close to 1, suggests that the central bank of China is successful in eliminating 98 per cent of the bilateral EMP during 2006-18. Such high level of intervention by the Chinese monetary authorities does not signify that the Yuan is fixed rather it implies that the Yuan is allowed to resettle itself around its free-float equilibrium value.

The evidence thus points to the behaviour of the Chinese Yuan and their monetary authority being different from that of other BRICS nations. The results show that the monetary authority of Brazil, Russia, India and South Africa allow their currency to float more freely as compared to Chinese authorities who follows a policy of rigorous intervention to maintain their currency within a band and prevent it from excessive appreciation or depreciation. Since the behaviour of the currency markets of Brazil, Russia, India and South Africa are more similar, leaving China, there can be a possibility of synchronization of markets and portfolio diversification which is being dealt with in the subsequent section. From the investors' point of view, it provides an insight into the co-movements of the currency markets and is indicative of the opportunity for portfolio re-allocation among the BRICS foreign exchange markets.

4.3 Market Synchronization: BRICS Foreign Exchange Market

Synchronization of currency markets is the association among them and is measured by the unconditional correlation between the logit transformation of the smoothed probabilities of the bull and bear regimes of the two markets. The smoothed probability of a given regime is obtained from Markov Switching analysis. For instance, if p_{it} is the probability of market i at period t for the bear regime, then the logit transformation of the probability is as follows:

$$logit = \log\left(\frac{p_{it}}{1 - p_{it}}\right)$$

The estimates of unconditional correlation of the logit transformations, as evident from Table 3, range from -0.16 to 0.46 in bear regime and from -0.01 to 0.46 in bull regime. The table shows that most foreign currency markets have a positive and significant correlation among them, the only exception is the correlation of the Chinese Yuan with Brazilian Real and Indian Rupee, which is negative in both the regimes and insignificant only in bull regime. It is also revealed from the table the Indian Rupee is having an insignificant correlation, although positive, with Russian Ruble in bull regime. The highest correlation is

between Brazilian Real and Russian Ruble in bear regime and between Brazilian Real and South African Rand in bull regime. Conversely the correlation is lower between the Chinese Yuan and Indian Rupee in both the regimes. Moreover, the magnitude and sign of correlation coefficients implies that the markets are synchronized and less opportunity is available with the investors for portfolio diversification, except the case with Chinese Yuan.

Table 3: Evidence on Currency Market Synchronization in BRICS

Bear Regime					
	Brazilian Real	Russian Ruble	Indian Rupee	Chinese Yuan	South African Rand
Brazilian Real	1				
Russian Ruble	0.46*	1			
Indian Rupee	0.13*	0.06*	1		
Chinese Yuan	-0.10*	0.08*	-0.16*	1	
South African Rand	0.37*	0.23*	0.12*	0.04*	1
Bull Regime					
	Brazilian Real	Russian Ruble	Indian Rupee	Chinese Yuan	South African Rand
Brazilian Real	1				
Russian Ruble	0.13*	1			
Indian Rupee	0.13*	0.01	1		
Chinese Yuan	-0.01	0.05*	-0.03	1	
South African Rand	0.46*	0.04**	0.06*	0.02	1

Note: * and ** denote significance at 1% and 5% level

Conclusions and Policy Implications

Exchange rate is one of the critical variables in open economies, whose stability is considered as one of the most important parameters in achieving high economic growth. A strong foreign exchange market has important implications for economic policies and international capital budgeting decisions as negative shocks affecting one market may be transmitted to another and can be a source of instability. It is observed that the BRICS currencies exhibit volatility and volatility clustering

during period of study. To understand the pattern of volatility, this paper has investigated the regime switching behaviour of the BRICS foreign exchange markets. It is found that Chinese Yuan is less volatile among BRICS currencies in both bear and bull regimes whereas South African Rand is the most volatile currency. The foreign exchange markets are affected by several crises, as evident from smoothed probability graphs. Besides, the persistence of the overall cycle, across all foreign currency markets, is uniformly higher for bear regime as compared to the bull regime with Chinese Yuan having the highest number of bear and bull regime cycles suggesting that the currency has gone through maximum phases of appreciation and depreciation as compared to other BRICS currency. Moreover, the Exchange Market Pressure estimates show that the BRICS currencies had gone through a depreciating phase during the crises periods to which the respective central banks responded with intervention, although the degree was higher for the Chinese central bank, among other BRICS countries. On the contrary, the least intervention is by the central bank of South Africa.

The econometric analysis had set out in identifying that the Chinese Yuan can be an attractive currency among the BRICS countries for the investors because its volatility is lower in both the regimes although the mean varies across regimes. On the other hand, South African Rand is having a high variance in both the regimes making it unattractive for the investors. However. as is evident from the market synchronization analysis, that there are very less opportunity for portfolio diversification as the movements in BRICS currency markets are synchronized, except the Chinese Yuan.

Endnotes

[1] However, many emerging market economies adopted the fixed exchange rate regime from crawling pegs in response to the crises such as the Mexican crisis in 1994-95, Asian crisis in 1997-98, Brazilian crisis in 1999 and the Argentinean crisis in 2001 etc. (Fiess and Shankar 2009)

[2] Krugman (1991), while presenting a model of exchange rate behaviour in a permanent target zone, advocates that the monetary authorities intervene in foreign exchange markets when the spot rate touches the defined currency band. Interestingly the model advocates that, even if the authorities have not intervened at all, the mere decision to intervene automatically corrects the exchange rate within the specified currency band.

[3] Supportive evidence in favour Meese and Rogoff (1983a,b) is demonstrated in Neely and Sarno (2002), Meese and Rose (1991), and Killian and Taylor (2003).

[4] For instance, some papers dealing with stock markets dynamics, the relationship of stock markets with other financial markets and oil markets in MSM framework are Guidolin and Timmermann (2006), Chesnay and Jondeau (2000), Tillmann (2004), Qiao et al. (2011), Chkili et al. (2011), Thomadakis (2012), Chan et al. (2011) and Dua and Tuteja (2016).

[5] In recent years, a large number of studies have used MSM to predict future price movements and to capture volatility dynamics of stock markets (see Balcilar et al. 2015)

[6] The initial year in the study is chosen to be 2006 on account of the following reasons. First, China abandoned the pegged exchange rate system and moved into a managed float exchange rate regime with reference to a basket of currencies from July 2005. Second, the formation of BRICS as a regional group was initiated with the first meeting of the leaders of the four countries namely Brazil, Russia, India, and China in September 2006 on the sidelines of the General Debate of the UN General Assembly to enhance development cooperation among these countries. Later on, in April 2011, South Africa is included in the regional group.

[7] For detailed Markov Switching estimation procedure, see Hamilton (1989, 1994) and Krolzig (1997, 2001)

[8] According to Weymark (1995), Exchange Market Pressure (EMP) measures the total excess demand for a currency in international markets as the exchange rate change that would have been required to remove this excess demand in the absence of exchange market intervention, given the expectations generated by the exchange rate policy actually implemented.

[9] The detailed description of the small open economy monetary model used to estimate the Exchange Market Pressure (EMP) is illustrated in Girton and Roper (1977) and Weymark (1995). The variables used in estimating the Exchange Market Pressure (EMP) for BRICS countries were extracted from OECD

database. The monthly data for foreign exchange reserves for BRICS countries were extracted from Federal Reserve Bank of St. Louis.

[10] The return on each foreign exchange is calculated by taking the first logarithmic differences in exchange rate denoted as: $\Delta \ln S_t = \ln S_t - \ln S_{t-1}$

[11] Detailed computations with regards to these cycles can be availed from the authors on request.

[12] The Intervention Index is available upon request.

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Appendix

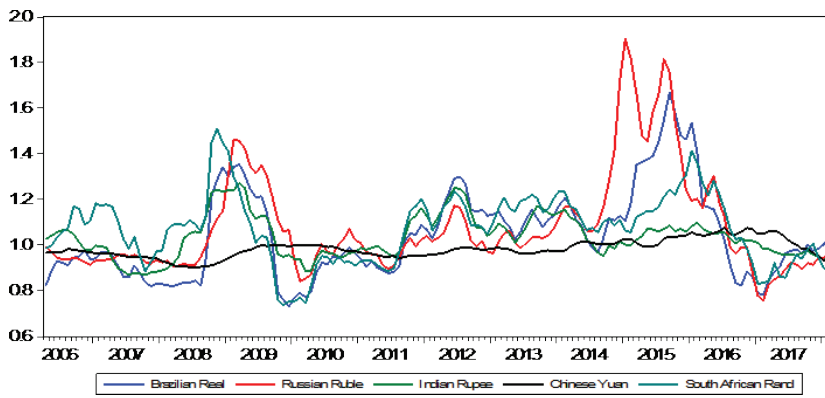
Table A1: Duration of Regime

	No. of Cycles	Duration of Regimes (in Days)		Total Duration (in days)
		Bear	Bull	
Brazilian Real	55	2665	1007	3672
Russian Ruble	45	2748	1200	3948
Indian Rupee	93	2094	1191	3285
Chinese Yuan	110	2347	1254	3601
South African Rand	61	2826	671	3497

Note: The duration of each regime was selected by sorting the smoothed probability which is above 0.80 for both Bear and Bull Regime.

The total table on the duration of bear and bull regime cycle of BRICS currency markets is available upon request

Figure B1: Intervention Index: BRICS Foreign Exchange Markets



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