The impact of exchange rate volatility on capital flows in BRICS economies

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ABSTRACT

This study intends to analyse the impact of exchange rate risk on equity returns and bond yields as well as the volatility spillover between the foreign exchange, equity and bond markets in the BRICS economies. To reach this objective, a multivariate GARCH-M with BEKK specifications is applied on weekly data obtained from Thomson Reuters DataStream. The findings of the paper show that exchange rate volatility has a positive impact on ten-year bond yields in all BRICS countries except in South Africa, where the volatility of exchange rate has a negative impact. In addition, volatility to exchange rate positively influences equity returns in Brazil, India and South Africa, while the influence on Chinese and Russian equity returns is negative. These findings show that equity returns increase with the increase in exchange rate volatility in Brazil, India and South Africa, and decrease in China and Russia. Furthermore, the results on volatility spillovers between the equity returns, bond yields and foreign exchange markets show that the transmissions are from capital markets to foreign exchange market in South Africa, while the volatility to currency markets influence capital markets in Russia. The results of the study give evidence of bidirectional volatility transmissions in Brazil and China. Surprisingly, in India, volatility is transmitted from foreign exchange markets to bond markets, while changes to equity influence the foreign exchange markets.

1. INTRODUCTION

The last two decades have seen an increase in the number of different bilateral and multilateral agreements, culminating in regional and global trade and financial integration. In such an integrated economy, exchange rates play an important role in securing cross-border investments and financial asset (FRBFS, 2001; Grambovas, 2003). Moreover, cross-border activities that involve shifting capital investments from one country to another trigger an increase in the level of portfolio or capital flows. These activities often affect the foreign exchange market. It is in this context that studies such as Odoyo, Muasya and Kenneth (2014), Ffrench-Davis (2003), Griffith-Jones (2003) and Kurihara (2006) have linked changes in the foreign exchange market to cross-border investment flows. For example, Ffrench-Davis (2003) shows that exchange rates have become an important factor determining the extent of trade as well as portfolio and direct investment flows in developing countries in the period 1990 to 1997.

The change in demand and supply for currencies owing to portfolio and international investment flows have impacted, to some extent, the relationship between asset returns/prices and exchange rates (Kanas, 2000; Urata and Kawai, 2000; Bénassy-Quéré, Fontagné and Lahrèche-Révil, 2001; Omorokunwa and Ikponmwosa, 2014; Jebran and Iqbal, 2016). Moreover, Mishra, Swain and Malhotra (2007: 344) suggest that the pricing of assets depends on a combination of exchange rates and returns of these assets. The authors make use of an unconditional linear factor version of the consumption-based asset pricing model, and report that exchange rates play a crucial role in the pricing of stocks. Moreover, they show that the risk contained in exchange rates significantly impact portfolio investments of small-size firms, thus explaining the trade-off between risk and returns on portfolio investments.

Literature abounds in supporting the underlying idea that exchange rates are the key determinants of stock returns as they contain important information for investors (Nieh and Lee, 2001; Kim, 2003; Phylaktis and Ravazzolo, 2005; Stavárek, 2005; Aloui, 2007; Bonga-Bonga, 2013). Hence, studies assessing the relationship between exchange rate volatility and returns on capital flows include Sekmen (2011), Caporale, Ali and Spagnolo (2015), Yang and Doong (2004) and Choi, Fang and Fu (2009). However, these studies provide mixed results in terms of the relationship between the two variables. For example, Caporale et al. (2015) make use of bivariate VAR GARCH in mean with BEKK specifications in assessing the relationship between exchange rates volatility and international investment flows. The authors find that the changes in exchange rate negatively affect equity market returns in Euro areas, such as Sweden and the UK. However, the authors also find a positive relationship between the two variables in Australia. With regards to the relationship

between exchange rate volatility and bond returns, Caporale et al. (2015) then show a negative relationship between the two variables in UK and Sweden.

Yet very few studies have been conducted on the interactions between the foreign exchange market and securities market in emerging and developing economies (see Bonga-Bonga and Hoveni, 2013 and Mishra et al., 2007), and those that do exist limit themselves to analysing the relationship between the level or change in exchange rate and capital markets. This study therefore focuses on the impacts of the volatility in the foreign exchange markets on the capital market, especially the returns on equity and bond yields markets in the BRICS (Brazil, Russia, India, China and South Africa) economies. Put differently, this paper assesses how foreign exchange risks are priced in equity and bond markets in the BRICS. The paper uncovers whether the relationship between exchange rate volatility and equity and bond returns is determined in the context of capital market line (CML), in that the expected risks counterbalances the expected returns or that exchange rate volatility creates a risky environment that compromises the returns in equity and bond markets. Another contribution of this paper will be to infer whether there exists evidence of equity and bond home bias in each of the BRICS.

Moreover, this paper will assess the extent of volatility shocks transmission between the foreign exchange market and the equity and bond markets.

Very few studies assess the extent to which exchange rate risks are prices in the equity and bond markets. For example, Jorion (1993) assesses the pricing of exchange rate risk in the US stock market. The author finds that exchange rate risk is not priced in the stock market and that the unconditional risk premium linked to foreign currency exposure is very small and never significant. Vassalou (2000) tests the pricing of exchange rate and foreign inflation risk in equities. The author finds that foreign inflation and exchange rate risk factors can explain part of the within-country cross-sectional change in equity returns. Moreover, Vassalou shows that home bias, at least in US equity portfolio, is not due to investors' effort to hedge their domestic inflation. Fidora et al. (2007) assess the role of real exchange rate volatility as driver for portfolio home bias and a possible explanation for home bias across financial assets. The authors find that real exchange rate volatility is an important factor for bilateral portfolio home bias, moreover, the authors how that a reduction of monthly exchange rate volatility reduces bond home bias by up to 60 pecentage points, and it reduces equity home bias by 20 percentage points. Smith (1992) makes use of the general model of optimal choice over risky assets to derive an estimable exchange rate equation. The author finds that equity values have a significant effect on exchange rate, especially for the Japanese-US dollar exchange rate. It is clear from past studies that none of the studies have uncovered the mechanism

and principles through which exchange rate risks are priced in equity and bond markets. To the best of our knowledge, this is in the first paper to assess the extent to which exchange rate risk affect equity and bond returns in emerging markets, especially BRICS economies.

To this end, this study makes use of a multivariate GARCH in mean model with BEKK specifications to account for the interaction between exchange rates volatility and returns on equity and bonds yields markets in the mean equation. In addition, volatility spillover between the three markets, namely foreign exchange, equity and bond markets, is assessed in the volatility equation.

The remainder of the study is structured as follows: section two reviews the literatures on the interaction between the foreign exchange, equity and bond markets, while section three describes the methodology employed in the study. section four then presents the data and estimations, as well as the interpretations of data analysis, and section five will draw the conclusions of this research and suggest policy implications.

2. LITERATURE REVIEW

A number of studies have assessed the impact of exchange rate volatility on asset prices/returns. For instance, Stefanescu and Dumitriu (2013) show how volatility in foreign exchanges markets impact asset returns and volatilities in the Romanian financial market. The authors find that exchange rate volatilities do not impact on prices of securities in the Bucharest Stock Exchange (BSE) for the period January 2000 to December 2007. However, they find significant influence of foreign exchange markets on the returns of assets in BSE for the period between the integration of Romania in the European Union (in 2007) and the global financial crisis.

In a similar study, this time in Sweden, Hatemi and Irandoust (2002) investigate the relationships between exchange rates and asset prices by making use of the vector autoregressive (VAR) model. The authors find that capital markets have an impact on foreign exchange market, in that the Swedish currency (Krona) appreciates following a rise in the prices of stock in Sweden.

In a later study, using the squares of residuals obtained from an autoregressive moving average model, Sekmen (2011) assesses the effects of the volatility in exchange rate on capital markets (equity and bonds) returns in the United States (US) for the period spanning from 1980 to 2008. The results of the study suggest that volatility in exchange rate impact negatively on returns of equity and bonds in the US.

Using a different approach, Fang and Miller (2002) analyses how a rise in the exchange rate (depreciation of Korean currency) influences capital markets returns. The authors make use of an

unrestricted bivariate generalised autoregressive conditional heteroskedasticity (GARCH) in a mean model on observations collected during the 1997 Asian crisis. Their empirical results suggest different channels through which a depreciated exchange rate influences the capital market in Korea. On one hand, a depreciated currency has a negative impact on assets returns, while on the other, high volatility in the exchange rate leads to an increase in returns of financial assets. The results are consistent with the principle of high risk and high returns correlation.

In an earlier study, Najang and Seifert (1992) also examine the relationship between financial asset returns and the volatility in exchange rates. The authors apply a GARCH model on a daily dataset from countries such as Canada, Germany, UK, USA and Japan over the period 1985 to 1991. Their results show that returns of capital markets positively impact on volatility in exchange rate. A year later, again in the US, Goldberg (1993) investigates the impacts of exchange rates as well as volatility in exchange rates on the flow of portfolio investments during the period January 1970 to April 1989. The findings show that the exchange rate does not impact on international portfolio flows.

In their assessment of the impact of exchange rates volatility on international flows of bond and equity, Caporale et al. (2015) apply a GARCH-M with BEKK specifications on a monthly dataset for Australia, Canada, the Euro area, Japan, Sweden, the UK and the US from January 1988 to December 2011. The authors show that exchange rate risk negatively impacts on international diversification of equity and bond investments. In addition, exchange rate risk decreases profitability of the bond and equity markets by increasing costs of financial investments in the selected countries.

Also focusing on the US and the Euro area, Erhmann, Fratzscher and Rigobon (2011) attempt to measure the interactions among financial assets within the US as well as between US and Euro area. The authors make use of a VAR model on data for the period between 1989 and 2008. Their findings shed light on the transmission mechanism within and across different asset classes, and show that the impacts of exchange rates volatility on other financial assets differs, depending on domestic economic realities.

In their investigation of the role played by foreign exchange market in explaining financial investments in a number of economies, Fidora, Fratzscher and Thimann (2007) made use of a Markowitz portfolio selection model. They found that a decrease in volatility in real exchange rate leads to a fall in capital market returns in a number of countries. They also found that uncertainty in exchange rates depresses bonds returns by 60% and equity returns by 20%.

Focusing specifically on UK, Indian, Germany and US, Panda and Parida (2013) examine the role played by currency market in influencing changes in prices of securities. Using an International Capital Assets Pricing Model (ICAPM) on daily observations between April 2003 and March 2008, the authors' findings show that volatility in exchange market negatively impacts on returns of financial investments in India. In addition, Panda and Parida indicate that currency volatility negatively affects the price of financial assets in India, Germany and UK.

Also examining the relationship between volatility in exchange market and prices of stock, Grambovas (2003) make use of a multivariate cointegration using data from Hungary, Czech Republic and Greece. The findings show evidence of a long run relationship between the two variables in Hungary. Several years later, Zia (2011) assesse the relationship between currency market and financial market in Pakistan, using an Engel-Granger cointegration on a monthly data sample spanning from January 1995 to January 2010. The results of this study, however, do not suggest evidence of long run interaction as well as causality between the two markets.

In a study considering both developed and developing economies, Tudor and Popescu-Dutaa (2012) evaluate the relationship between exchange rate volatility and returns in capital market in the UK, US and France, and Brazil, Russia, India, China, Korea and South Africa from the period 1997 to 2012. Applying a Granger causality test, the authors find that the interactions between stock markets and exchange rate volatility are significant in Korea. Moreover, fluctuations in exchange rates affect returns of equity in Brazil and Russia.

In Nigeria, Omorokunwa and Ikponmwosa (2014) consider the nature of the relationship between international investments and exchange market. The authors apply an Error Correction Models on dataset spanning from 1980 to 2011. The results of their empirical study indicate weak impacts of volatility in currency market financial investments in the short run, while in the long run there are positive and significant impacts of volatility in exchange rate impact on capital markets.

In some countries from the East Asia Pan, Fok and Liu (2007) investigate the relationship between the prices of assets and foreign exchange. Making use of various econometric tests such as the impulse responses test, variance decomposition test and Granger causality test, the results show that the two markets influence one another in Hong Kong before the 1990s Asian financial crises. Moreover, the foreign exchange influence prices in financial market in Malaysia, Thailand and Japan, while the financial market cause exchange rate movement in Korea and Singapore. In addition, Pan et al. (2007) indicate that during the period of the crisis, among all the countries, the capital market in Malaysia alone do not react to foreign exchange. However, also in Malaysia,

Ibrahim (1999) analyses the causal interactions between prices of financial assets and macroeconomic determinants. Employing a bivariate error correction model, the author found evidence of effects of changes in foreign exchange on prices in capital market.

In Japan, Kurihara (2006) focuses on the macroeconomic factors affecting capital markets in the phase of recovery of the Japanese economy. To this end, the author make use of VAR in impulse responses on daily dataset of price of securities for the period running from March 2001 to September 2005. The findings reveals that both the foreign exchange rate and prices of financial in the US impacted on prices in the capital market in Japan.

In another relevant study, Aggarwal et al. (2010) investigate the relationship between returns in capital market and currency market in India. The authors employ a Granger causality test on daily indices for the sample period October 2007 to March 2009, and conclude that there are causal effects of returns of financial assets on foreign exchange market. Also in India, Najaf and Najaf (2016) consider the co-movement between the capital market and returns of foreign exchange rate. The authors use a Granger causality test on observations from October 2008 to March 2010, and find that volatility in exchange rate is negatively related to movement in capital market. The underlying idea here is that foreign exchange market is important in determining returns of assets in Indian market.

Bonga-Bonga and Hoveni (2013) similarly assess the level of transmissions of volatility between capital market and currency market in South Africa. Making use of multi steps GARCH models on weekly datasets for the period running from first July 1995 to thirty-first October 2010, the authors find that volatility in equity market is transmitted into currency market. The authors note that these findings may be explained by the significant role of international investors in the capital market in the country.

In a similar study, Adjasi, Harvey and Agyapong (2008) investigated the interactions between capital market returns and currency market in Ghana. By using the GARCH model, the authors aimed to determine if volatility in exchange rate impacted on the returns of the capital market in the Ghana Stock Exchange for a period spanning 1995 January to June 2005. The results of the study suggest an inverse relationship between the two markets, stemming from the foreign exchange market and affecting the capital market. In other words, the foreign exchange market has a negative impact on capital market returns.

3. METHODOLOGY

This study investigates the impact of exchange rate volatility on portfolio investments, specifically equity returns and bond yields in BRICS countries, by making use of a multivariate GARCH model. Given the importance of the GARCH models, be it univariate or multivariate models, which have the ability to capture some characteristics of financial time series data that other econometric techniques do not. Hence, the study will make use of a standard multivariate GARCH model with the BEKK specifications, introduced by Baba, Engle, Kraft and Kroner (1990) and improved by Engle and Kroner (1995). It is worth noting that the GARCH model with BEKK specification overcomes the concern of positive definiteness of the variance covariance matrices and permits a large number of parameters.

In particular, the current study investigates the impact of volatility of exchange rates on capital flows from investing in financial markets, thus justifying the use of the BEKK specification as well as a GARCH-in-mean (GARCH-M). The multivariate GARCH-M with BEKK representation will thus be employed in this research because the model would, on one hand, straightforwardly estimate the conditional covariance (H_t or σ_t^2) of exchange rates, and on the other hand, allow for the inclusion of the conditional variance into the mean equation in order to assess its impact on the equity returns and bond yields without reservation as per the reference study (Caporale et al., 2015). GARCH with BEKK specifications best predicts the future covariance matrix (Caporale et al., 2006; Karolyi, 1995). In addition, BEKK has a quadratic system that ensures that the matrices of the conditional covariance are positive definite, in contrast to other multivariate GARCH models such as the VEC, proposed by Bollerslev et al. (1988) (Bonga-Bonga and Mwamba, 2011; Caporale et al., 2015).

Econometric model

In this research paper, volatility is measured based on conditional variance as per the study by Caporale et al. (2015: 74). However, the mean equation of the multivariate GARCH-M with BEKK specifications, as employed by this study, is expressed as:

$$Eq_t = \alpha_1 + \varphi_1 X_{1t} + \beta_1 H_t + \varepsilon_{1t} \quad (1)$$

$$B_t = \alpha_2 + \varphi_2 X_{2t} + \beta_2 H_t + \varepsilon_{2t} \quad (2)$$

$$E_t = \alpha_3 + \tau_3 Eq_t + \theta_3 B_t + \beta_3 H_t + \varepsilon_{3t} \quad (3)$$

$$\varepsilon_{it} = \sqrt{h_t}.z_t \quad (4)$$

$\varepsilon_t = H_t z_t$ with $z \xrightarrow{\quad} IID; \quad E(z_t) = 0;\ and\ Var(z_t) = I_{n*n}$ (5)

$\varepsilon_t \sim (0, h_t)\ where\ E(\varepsilon_t) = 0\ and\ var(\varepsilon_t) = h_t$, with time varying variance. (6)

$H_t = \omega\omega' + A\varepsilon_{t-1}\varepsilon'_{t-1}A' + BH_{t-1}B'$ (7)

where the three equations Eq_t, B_t and E_t represent the equations equity returns, bond yields and exchange rate respectively. In addition, H_t represents the conditional variances (volatility) of exchange rate, X_{1t} stands for US equity returns (S&P 500) and X_{2t} represents US ten-year bond yields.

Furthermore, φ_1 measures the effects of S&P 500 on equity returns in BRICS nations and φ_2 is the parameter estimate measuring the response of bond yields to US bond yields. The parameters τ_3 and θ_3 measure the responses of exchange rates to equity returns and bond yields respectively in all the BRICS economies. The impacts of equity returns, bond yields as well as exchange rates to volatility in exchange rates are measured by the parameters β_1, β_2 and β_3 respectively. Lastly, α_1, α_2 and α_3 are the constant or means in each equation. These parameters inform the values that take equity returns, bond yields and exchange rates when all exogenous variables are not considered (set to be equal to zero) in each mean equation.

The variance equation (eq. 7) can be written in matrix form as follows:

$$\begin{bmatrix} h_{11,t} & h_{12,t} & h_{13,t} \\ h_{21,t} & h_{22,t} & h_{23,t} \\ h_{31,t} & h_{32,t} & h_{33,t} \end{bmatrix} = \omega'\omega + A' \begin{bmatrix} \varepsilon^2_{1,t-1} & \varepsilon_{1,t-1}\varepsilon_{2,t-1} & \varepsilon_{1,t-1}\varepsilon_{3,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon^2_{2,t-1} & \varepsilon_{2,t-1}\varepsilon_{3,t-1} \\ \varepsilon_{3,t-1}\varepsilon_{1,t-1} & \varepsilon_{3,t-1}\varepsilon_{2,t-1} & \varepsilon^2_{3,t-1} \end{bmatrix} A +$$

$$B' \begin{bmatrix} h_{11,t-1} & h_{12,t-1} & h_{13,t-1} \\ h_{21,t-1} & h_{22,t-1} & h_{23,t-1} \\ h_{31,t-1} & h_{32,t-1} & h_{33,t-1} \end{bmatrix} B \quad (8)$$

$$\omega = \begin{bmatrix} \omega_{11} & 0 & 0 \\ \omega_{21} & \omega_{22} & 0 \\ \omega_{31} & \omega_{32} & \omega_{33} \end{bmatrix}, A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix},\ B = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}$$

where the elements on the diagonal $h_{11,t}$, $h_{22,t}$ and $h_{33,t}$ represent the variances of equity returns, bond yields and exchange rate respectively. The off-diagonal elements $h_{12,t}$ and $h_{21,t}$ represent the covariance between bond yields and equity returns respectively; $h_{13,t}$ and $h_{31,t}$ represent the covariance between exchange rate and equity respectively; and $h_{23,t}$ and $h_{32,t}$ represent the covariance between exchange rate and bond yields respectively. In the

conditional variance equation, equation (7), the coefficients ω, A, and B are the vectors of intercepts, coefficients of lagged squared residuals and the coefficients of the lagged conditional variance and covariance respectively. Moreover, in equation (7), the matrices A and B are past or lag one ARCH and GARCH parameters matrices respectively. Lag ARCH represents innovations and/or shocks from the recent past while lag GARCH stands for volatility persistence. It is important to note that the co-transmissions of volatility and shocks between the three markets are identified through the off-diagonal parameters of innovation matrices or lag ARCH.

SECTION 4: DATA, ESTIMATION AND DISCUSSION OF RESULTS

Data description and preliminary analysis

As indicated in the first section, this study intends to analyse the impact of exchange rate risk on equity returns and bond yields as well as the volatility spillover between the foreign exchange, equity and bond markets in the BRICS economies. To reach this objective, weekly data from Thomson Reuters DataStream are used. The dataset consists of each BRICS country's exchange rate, namely the Brazilian Real, Russian Ruble, Indian Rupee, Chinese Yuan and South African Rand, against the US dollar. In addition, the study makes use of stock market equity indices of each BRICS country, namely the Bovespa Equity Index for Brazil; the Russian Trading System Index (RTSI), the National Stock Exchange (NSE) NIFTY 50 index for India; the Shanghai Composite Index for China and FTSE/JSE All Share Index for South Africa. The other data used are of the ten-year government bond yields for each BRICS country. The sample data depend on their availability, thus vary among each country: data for India and South Africa span from November 1996 to November 2016; Brazil's data are from January 2006 to November 2016; Russia's data cover April 2003 to November 2016; and China's data include June 2002 to November 2016.

Tables 1 through 5 display the results of the descriptive statistics of the variables under investigation for all BRICS country.

Table 1: Descriptive statistics in Brazil

	Equity returns	Bond yields	Exchange rate Brazilian Real/US Dollar
Mean	0.1821	12.4677	0.0774
Standard deviation	3.6507	1.6199	2.2494
Kurtosis	3.3022	0.3435	14.3917
Skewness	-0.0663	0.4399	1.5414
Jarque Bera (JB)	251.88***	20.7637***	5023.716***

NB: ***significant at 1%
** significant at 5%
* significant at 10%

Table 1 reports the results of the descriptive statistics of the three variables for Brazil. Results suggest that long-term (ten-year) government bond in Brazil offer a higher yield on average compared to other financial series, exchange rates and equity in the country. In addition, the long-term government bond records an average yield of 12.468 percent in Brazil. The mean returns stand around at zero for the Brazilian equity (0.1821) and exchange rate Brazilian Real against US Dollar (0.0774). Table 1 further shows that equity returns in Brazil are more volatile, recording a standard deviation of 3.651 compared to the other two series (bond yields and exchange rate). Moreover, long term bond yield with a standard deviation of 1.620 exhibits less volatility compared to exchange rates with a standard deviation of 2.249. In addition, all series exhibit positive excess kurtosis. The series are mostly skewed to the right, except equity, which tends to skew to the left. The Jarque-Bera shows that the series are all not normally distributed at one percent.

Table 2: Descriptive statistics in Russia

	Equity returns	Bond yields	Russian Ruble/US Dollar
Mean	0.3589	8.5946	0.1234
Standard deviation	4.6730	1.9055	2.1907
Kurtosis	14.1703	1.3152	47.2159
Skewness	0.4234	1.1764	2.4662
Jarque Bera	5879.57***	213.1882***	65814.64***

NB: Jarque-Bera for normality test
*** significant at 1%
** significant at 5%
* significant at 10%

Table 2 displays the descriptive statistics results of the series in Russia. It reports positive average returns and yields for all variables, with the long-term government bond offering the highest yields, with an average of 8.595. The standard deviations are positive in all series, indicating that all

variables are volatile. In addition, table 2 shows that Russian equity exhibits higher volatility with 4.673, followed by the exchange rate Ruble/US Dollar, with 2.191. All variables have positive excess kurtosis. Furthermore, exchange rate records the highest value of excess kurtosis (47.212), followed by Russian equity (14.170). These results indicate that international investors should expect the exchange rate to be highly volatile in the future (i.e. high appreciation or high depreciation of US Dollar) given the larger value of its excess kurtosis. The series exhibit skewness to the right, and the Jarque-Bera normality test suggests that all series are not normally distributed at the one percent level of significance.

Table 3: Descriptive statistics in India

	Equity returns	Bond yields	Indian Rupee/US Dollar
Mean	0.3156	8.5007	0.0633
Standard deviation	3.8149	1.9862	0.9105
Kurtosis	3.1005	-0.0148	7.9798
Skewness	-0.4548	0.7985	0.5422
Jarque Bera	448.5491***	110.6362***	2790.564***

NB: Jarque-Bera for normality test
*** significant at 1%
** significant at 5%
* significant at 10%

Table 3 reports the descriptive statistics of the series in India. It suggests that all series are volatile, judging by the positive values of the standard deviations. India's equity returns are the most volatile (3.815), followed by Indian long-term government bond yields (1.986). Exchange rates exhibit lower volatility among the series, with 0.910. All series are not normally distributed at one percent (rejecting the null hypothesis of being normally distributed at one percent) in India. In addition, the series offer a positive average returns (gains) in general, with Indian long-term government bond yields recording 8.501 percent and Indian equity offering 0.03156 percent. In addition, all variables exhibit positive skewness, except the equity index, which tends to skew to the left. The ten-year government bond has a negative value standing around zero (0.01479). Yet the excess kurtosis of the two other series are positive, with exchange rate recording a higher value (7.979) than the NIFTY 50 equity returns (3.10). This result indicates that the volatility of exchange risk can reach an extreme value (high or low).

Table 4: Descriptive statistics in China

	Equity returns	Bond yields	Chinese Yuan/Us Dollar
Mean	0.1641	3.6254	-0.0262
Standard deviation	3.7310	0.5362	0.2435
Kurtosis	2.3306	-0.6262	12.3056
Skewness	-0.4386	0.4305	0.0922
Jarque Bera	191.3176***	35.6636***	4689.518***

NB: Jarque-Bera for normality test
*** significant at 1%
** significant at 5%
* significant at 10%

The descriptive statistics on the series in China as reported in table 4 suggest that, on average, bond yields and equity returns yield a gain to investors, while the average of the exchange rate series is negative. In addition, ten-year government bonds in China offer a higher yield with 3.6254 percent than equity return at 0.1641 percent. Table 4 further suggests that exchange rate Yuan/US Dollar exhibits high excess kurtosis with 12.306, while the long-term bonds exhibit negative excess kurtosis 0.626. With regards to the skewness, Chinese long-term government bonds and the Yuan/US Dollar exchange rate tend to skew to the right (i.e. the return in bond increase with time), while Chinese equity skews to the left (showing a decrease in returns in the future). Among the series, Chinese equity exhibits higher volatility given the value of its standard deviation, 3.7309. The Jarque-Bera test for normality suggests that all series are not normally distributed at one percent.

Table 5. Descriptive statistics

	Equity returns	Bond yield	South African Rand/US Dollar
Mean	0.2425	10.0058	0.1228
Standard deviation	2.8796	2.7210	2.2051
Kurtosis	5.7918	-0.2211	3.9570
Skewness	-0.5104	0.9875	0.7287
Jarque Bera	1487.605***	171.4188***	764.7651***

NB: Jarque-Bera for normality test
*** significant at 1%
** significant at 5%
* significant at 10%

Table 5 depicts the descriptive statistics of the series in South Africa. It shows that, on average, bond and equity offer positive returns (gains), and the average of the exchange rate is positive. Moreover, South African long-term government bond yields record the highest returns, with

10.0058 percent. The series are not normally distributed as suggested by the rejection of the null hypothesis at one percent of the Jarque-Bera normality test. Unsurprisingly, in South Africa the variables are all volatile, and they all tend to have the same level of volatility when considering their standard deviations standing around 2. In addition, South African equity as well as Rand/US Dollar exchange rate both exhibit positive excess kurtosis with 5.792 and 3.957 respectively, while the South African long-term government bond exhibit negative excess kurtosis. With regard to the skewness, all variables tend to increase in value as they have positive values, except for South African equity, whose returns will tend to decrease in the future.

In order to determine the impact of exchange rate volatility equity returns and bond yields, Tables 6 to 10 display the results from the estimations of the mean equations (1 to 3) as well as the variance equation (28) of the multivariate GARCH in mean for each BRICS country. The conditional mean equation in each table indicates how changes/volatility in exchange rates impact on the equity returns and ten-year bond yields in all BRICS countries, in accordance with the aim of the study indicated above.

Furthermore, the conditional variance equation in each table (from 6 to 10) summarises the results of volatility spillover between the foreign exchange, equity and bond markets in each of the BRICS economies, as represented in equation (7) and expanded in equation (8). The results of the conditional variance as reported in tables 6 to 10 indicate how shocks/innovations from j affect i. The order of variables is assumed to be equity, bond and exchange rate, with subscript 1 standing for equity returns, subscript 2 for bond yields and subscript 3 for exchange rates. For instance, shocks from bonds and exchange rate to equity are measured by a_{12} , a_{13} respectively, and volatility from bond and exchange rate to equity are measured by b_{12} and b_{13} respectively. Shocks from equity and exchange rate to bond are measured by a_{21} and a_{23} respectively, and volatility from equity and exchange rate to bond are measured by b_{21} and b_{23} respectively. Shocks from equity and bond to exchange rate are measured by a_{31} and a_{32} respectively and volatility spillovers from equity and bond to exchange rate are measured by b_{31} and b_{32} respectively. Shocks that are transmitted from equity to equity are measured by a_{11}, shocks from bond to bond are measured by a_{22} and shocks from exchange rate to exchange rate are measured by a_{33}. Volatility spillovers from equity to equity are measured by b_{11}, volatility spillovers from bond to bond are measured by b_{22} and volatility transmissions from exchange rate to exchange rate are measured by b_{33}. ARCH represents innovations or/and shocks while GARCH stands for volatility as specified in equation (7). Therefore, transmissions of disturbances from one market to others are done through

the off-diagonal parameters (a_{ij} and b_{ij}; $i \neq j$) of innovations (ARCH) and volatility (GARCH) matrices (Caporale et al., 2015).

Tables 6 through 10 display the estimation results of the multivariate GARCH-in-mean for Brazil, Russia, India, China and South Africa respectively.

Table 6: The estimated multivariate GARCH-M BEKK model for Brazil

	Equity returns (s=1)	Bond yields (s=2)	Exchange rates (s=3)
Conditional mean equation			
α_s	-1.009***	7.3856***	1.3467***
β_s	0.3436***	0.7934***	0.0394
φ_s	1.1305***	0.9991***	
τ_3			-0.4542***
θ_3			-0.0978***
Conditional variance equation			
ω_{1s}	1.0532***		
ω_{2s}	-0.0407	0.2072***	
ω_{3s}	0.2004***	0.086	0.0058
a_{1s}	-0.272***	-0.0065*	-0.0774***
a_{2s}	-0.2364**	0.9959***	0.0188
a_{3s}	0.1048**	0.0037	0.1372***
b_{1s}	0.8960***	-0.0193	0.0151***
b_{2s}	0.352***	0.1183	-0.0869**
b_{3s}	-0.1382***	0.0433***	0.9746***

Note: *** indicates statistical significance at 1% level
** indicates statistical significance at 5% level
* indicates statistical significance at 10% level

The results displayed in table 6 in the conditional mean equation indicate that exchange rate volatility has a positive impact on equity and ten-year bond yields in Brazil. However, the results show that volatility in the exchange rate does not influence the Brazilian Real/US Dollar exchange rate. US equity returns (S&P 500) and ten-year bond yields have significant and positive impacts on Brazilian equity returns and ten-year bond yields respectively. In addition, ten-year bond yields and Brazilian equity returns impact negatively on exchange rates returns.

With regards to the conditional variance equation, table 6 shows that there is evidence of bidirectional shock transmissions that are statistically significant between variables of the study in general. However, bond yields do not influence equity returns, since the transmissions of the shocks and volatility are not significant. In addition, there is no evidence of shock spillovers

between exchange rate and bond yields. The results suggest that volatility and shocks spillover positively and negatively respectively into equity returns. However, volatility to exchange rate is negatively transmitted into bond yields. The spillovers of volatility from capital markets to currency markets are negative and positive for equity and bond respectively, while shocks transmissions run positively from equity markets to exchange rate. Equity markets are reported to influence bond markets, focusing on both shocks and volatility. Table 6 indicates that there are bidirectional volatility spillovers between capital markets and currency markets.

Table 7: The estimated multivariate GARCH-M BEKK model for Russia

	Equity returns (s=1)	Bond yields (s=2)	Exchange rates (s=3)
Conditional mean equation			
α_s	0.1017	8.2704***	1.957***
β_s	-0.0189***	0.1803***	-0.2200
φ_s	0.8689***	-0.405***	
τ_3			-0.2200***
θ_3			-0.3051***
Conditional variance equation			
ω_{1s}	0.4396***		
ω_{2s}	-0.0441**	0.0108	
ω_{3s}	0.0888**	-0.1013	-0.053
a_{1s}	0.2655***	0.0078**	0.0109**
a_{2s}	-0.2367**	0.8253***	0.2169***
a_{3s}	-0.0056	-0.011	0.2039***
b_{1s}	0.9588***	-0.0007	-0.0041*
b_{2s}	0.2416***	0.6661***	0.0046
b_{3s}	-0.0105	0.0125***	0.966***

Note: *** indicates statistical significance at 1% level
** indicates statistical significance at 5% level
* indicates statistical significance at 10% level

The results of the conditional mean equation, as displayed in table 7, indicate that exchange rate volatility has a positive impact on Russian ten-year bond yields and a negative impact on Russian equity returns. The results do not show evidence that volatility in exchange rate influences the Russian Rubble/US Dollar exchange rate. US equity returns (S&P 500) positively influence Russian equity returns, while US ten-year bond yields have a negative impact on Russian ten-year bond yields. In addition, Russian ten-year bond yields as well as Russian equity returns impact negatively on exchange rates returns. The negative effects of the exchange rate volatility on the equity returns in Russia may reflect the effects of the 2014 currency crisis triggered by sanctions

against Russia for invading Ukraine. These sanctions (i.e. limitations on access to foreign financial markets, borrowings and financial transactions) alongside the fall in the prices of oil negatively impacted on the value of Russian Ruble, leading to restriction of capital inflow in favour of an outflow of capital from Russia. The country has thus become less attractive to local as well as international investors owing to significant increase in financial risk. In sum, these sanctions have affected different financial markets in Russia.

Furthermore, the results of the conditional variance equation presented in table 7 report that in Russia, the evidence of transmissions of volatility and shocks are statistically significant in all markets. However, shocks (news or information) are positively transmitted from exchange rates to investments, equity returns and bonds yield, while the volatility transmissions are negatively transmitted from exchange rates to equity returns. Furthermore, there is positive transmission of volatility from bond yields to exchange rates. Table 7 further suggests that shocks are positively transmitted from bonds to equity. Transmissions from equity to bonds are negative and positive for shocks and volatility respectively. Moreover, the transmissions of shocks and volatility from exchange rate to capital markets are stronger, judging by the results reported in table 7. Finally, volatility to exchange rate is more influential on capital markets than vice versa.

Table 8: The estimated multivariate GARCH-M BEKK model for India

	Equity returns (s=1)	Bond yields (s=2)	Exchange rates (s=3)
Conditional mean equation			
α_s	-0.0341	7.5003***	3.0434***
β_s	0.2086*	0.2425***	0.0329
φ_s	0.3677***	0.0552***	
τ_3			-0.0569***
θ_3			-0.3909***
Conditional variance equation			
ω_{1s}	0.2682***		
ω_{2s}	-0.0332	-0.0258	
ω_{3s}	-0.0062	0.0386**	0.0002
a_{1s}	0.1868***	-0.0101***	-0.0032
a_{2s}	-0.1381**	0.7732***	0.2459***
a_{3s}	-0.1327**	-0.0191	0.2388***
b_{1s}	0.9775***	0.001	0.0002
b_{2s}	0.1465***	0.6825***	-0.1334***
b_{3s}	0.0194**	0.0037	0.9726***

Note: *** indicates statistical significance at 1% level
** indicates statistical significance at 5% level
* indicates statistical significance at 10% level

The results displayed in the conditional mean equation of table 8 indicate that exchange rate volatility has a positive impact on equity as well as ten-year bond yields India. However, the results report that volatility in exchange rate has no influence on the Indian Rupee/US Dollar exchange rate. US ten-year bond yields and S&P 500 have a significant and positive impact on Indian ten-year bond yields and equity returns. In addition, the ten-year bond yields as well as Brazilian equity returns impact negatively on exchange rates returns.

The results reported in the conditional variance of table 8 indicate that in India, there is no evidence of volatility and shocks transmissions from exchange rate to equity. It is also important to note that the volatility transmissions from bond yields to equity returns and exchange rate are insignificant, as well as the shock transmission from bond yields to exchange rate. Table 8 indicates that the information/shocks and volatility are respectively positively and negatively transmitted from currency markets to bond yields. There is evidence of positive and negative transmissions of shocks and volatility from equity returns to exchange rate. Volatility and shocks that occur in the equity market influence bonds markets positively and negatively respectively. However, only shocks in the bond markets are transmitted in equity markets. In brief, table 8 suggests that any

form of disturbance to foreign exchange markets tend to influence bond markets more than equity markets, while foreign exchange markets are affected by equity markets.

Table 9: The estimated multivariate GARCH-M BEKK model for China

	Equity returns (s=1)	Bond yields (s=2)	Exchange rates (s=3)
Conditional mean equation			
α_s	0.5132***	3.4500***	-1.9193***
β_s	-1.7145***	1.1691***	-0.0829
φ_s	0.2319***	-0.0706***	
τ_3			-0.0022
θ_3			0.6046***
Conditional variance equation			
ω_{1s}	0.5192***		
ω_{2s}	-0.0397***	-0.0119*	
ω_{3s}	0.0318***	-0.0064	-0.0129*
a_{1s}	-0.157***	-0.0061***	-0.0064***
a_{2s}	1.1822***	-0.7147***	0.2196***
a_{3s}	1.0681***	-0.0748***	-0.3272***
b_{1s}	-0.9519***	-0.0079***	-0.0015
b_{2s}	-3.9840***	0.7239***	0.0821***
b_{3s}	-3.3869***	-0.0370***	0.9313***

Note: *** indicates statistical significance at 1% level
** indicates statistical significance at 5% level
* indicates statistical significance at 10% level

The results of the conditional mean equation as reported in table 9 indicate that exchange rate volatility has a positive impact on Chinese ten-year bond yields and a negative impact on Chinese equity returns. In contrast, the results do not give evidence that volatility in exchange rate impacts on exchange rate returns for the Chinese Yuan/Us Dollar, judging by the insignificance of the parameter estimate. The results further indicate that US S&P 500 positively affects Chinese equity returns, while US ten-year bond yields have a negative influence on Chinese ten-year bond yields. In addition, Russian ten-year bond yield have a negative effect on exchange rates, while Chinese equity returns positively impact on exchange rates returns.

The results of the conditional variance equation displayed in table 9 indicate that volatility transmission from exchange rate to equity returns does not exist, as it is insignificant. The results show that the shocks transmit from exchange rate to capital markets, and is positive to bond yields while negative to equity returns. In addition, volatility is positively transmitted from exchange rate

to capital markets, in particular, bonds. It is worth noting that disturbances to capital markets influence currency markets. This finding is consistent with the findings of the study by Muhammad and Rasheed (2002), who conclude that bidirectional volatility interactions between the two markets (currency and equity markets) exist. Table 9 further suggests that volatility and shocks are transmitted negatively from bonds yields to equity returns, while the transmissions of volatility and shocks are negative and positive respectively. These findings suggest that the spillovers of volatility and shocks between markets are equally important in China in both directions.

Table 10: The estimated multivariate GARCH-BEKK model for South Africa

	Equity returns (s=1)	Bond yields (s=2)	Exchange rates (s=3)
Conditional mean equation			
α_s	-6.0872***	20.1191***	1.4458***
β_s	1.2756***	-3.3409***	-0.2063***
φ_s	0.7347***	1.6581***	
τ_3			-0.2692***
θ_3			-0.0041
Conditional variance equation			
ω_{1s}	0.4308***		
ω_{2s}	0.0942***	-0.1767***	
ω_{3s}	1.007***	-0.2812***	0.2142***
a_{1s}	-0.2063***	0.0177**	0.0034
a_{2s}	-0.1331***	0.9277***	-0.0386**
a_{3s}	0.0542***	-0.0041	-0.0457***
b_{1s}	0.9787***	-0.0092**	0.0036
b_{2s}	0.0944***	0.3579***	-0.0085
b_{3s}	-0.0529***	-0.0103	0.8736***

Note: *** indicates statistical significance at 1% level
** indicates statistical significance at 5% level
* indicates statistical significance at 10% level

The results of the conditional mean equation as displayed in table 10 suggest that exchange rate volatility has a positive impact on equity, while the impact is negative on ten-year bond yields as well as the Rand/US Dollar exchange rate. US S&P 500 and ten-year bond yields have a significant and positive impacts on Brazilian equity returns and ten-year bond yields respectively. In addition, South African ten-year bond yields as well as South African equity returns impact negatively on exchange rate returns. The negative effects of exchange rate volatility on bond yields in South Africa is owing to the high level corruption affecting the public governance. In contrast with other BRICS economies, investors are aware that the exchange rate volatility in South Africa may be long lasting, thus maintaining an uncertain environment.

The results in the conditional variance equation indicate that no volatility transmissions exist between foreign exchange markets and bond market, and shocks to bond market do not influence exchange rate. There is also no evidence of shocks and volatility transmissions from exchange rate to equity return. The shocks and volatility spillovers are respectively all positively and negatively significant from equity to the exchange rate. These findings are consistent with finding of stud by Bonga-Bonga and Hoveni (2013), who explain this phenomenon in terms of the presence of international investors in the stock capital markets in the country. Shocks and volatility run negatively and positively respectively from equity returns to bond yields, and volatility and shocks to bond respectively negatively and positively influence equity returns. These findings show that the transmissions from capital markets to currency market are more important than the inverse, since negative effects have more impact than the positive. Thus, there is inconsistency between these findings and the conclusions drawn by Huzaimi and Liew (2004), suggesting that movements in exchange rates yield uncertainty in assets markets, thus fluctuations in their prices are likely to occur.

In summarizing the analysis of results, it is important to note that the increase in bond yields reflect the decrease in bond prices, thus the results of the conditional mean equation reported in tables 6 to 10 show that in most of the BRICS economies, exchange rate volatility or risk reduces the value of prices of bond except in South Africa, where risk increases the prices of bonds. These outcomes lead investors to switch to equity markets, where high exchange rate risk are compensated by high returns as investors choose to remain on the security market line. These findings are in line with the conclusion drawn by Phylaktis and Ravazzolo (2005), who show that returns in stock market and exchange rates volatility have a positive relationship. The authors explain their findings by pointing to the fact that US markets play a significant role in the relation between stock markets and foreign exchange market in emerging economies, since these markets are integrated with US markets.

With regard to the volatility transmissions, one can conclude that in all countries under study, the volatility (through ARCH and GARCH) spillovers between the three markets are mostly significant in general. While volatility spillovers are more important from bond yields and equity returns toward exchange rates, and from equity returns to bond yields, exchange rate volatility is still transmitted to financial markets. Thus any form of disturbance (innovations as well as variations) in one market is transmitted to others, hence the three markets to some extent impact on one another. This conclusion is consistent with most studies on the relationship between stock markets and foreign exchange rate market, and their dynamic linkages (Bonga-Bonga, 2013;

Morales, 2008; Mishra et al., 2007; Yang and Doong, 2004; Duncan and Kabundi, 2011). The underlying idea is that financial markets in emerging nations are mostly characterised as being very volatile, suggesting that prices in these markets adjust more often. Interactions between markets will also tend to strengthen as a result of an unusual adjustment of prices of financial assets (Bae, Karolyi and Stulz, 2003). Therefore, on one hand, there is high probability that variation in one asset affects the setting of the price of other assets. On the other hand, the volatility transmissions from exchange rate to bond and equity returns can be explained by the fact that agents alter their portfolio investments based on uncertainty in exchange market.

To illustrate the above arguments, Bonga-Bonga (2013) indicates that shocks in South African equity market positively affect conditional volatility of exchange rates. However, these findings are inconsistent with those of Shah, Hyder and Pervaiz (2009), Maghrebi (2006), Sifunjo and Mwasaru (2012) and Odoyo et al. (2014). As For example, Shah et al. (2009) state that exchange rates uncertainty creates disequilibrium in stock markets because of the expectation that investors would be affected. The results also indicate that disturbances that occur in exchange rates to some extent positively affect the returns of equity and bond, except in China and Russia: in Russian equities and in Chinese bonds the effects are negative. In general, these findings are consistent with those presented by studies by Kim (2003) and Fang and Miller (2002). Indeed, Kim indicates that the important increase in free capital (investments) worldwide makes the foreign exchange rate an important element in the stock profitability. In contrast, Chkili and Nguyen (2014) argue that uncertainty in the currency market does not disrupt stock markets, thus their returns/prices.

S&P 500 returns positively affect equity returns in all five BRICS nations, indicating that a one percent increase in S&P 500 returns yields a rise in equity returns, mostly in Brazil followed by Russia, while Chinese equity stands at around 0.2319 percent. These findings are consistent with the conclusion offered by Karell (2013), who indicates evidence of significant influences of returns from US stock markets on other equity markets. With regard to the ten-year long-term bond, bond markets in all BRICS economies react positively to an increase in US bonds except for Russia and China, where the yields of the long-term bond yields fall below zero (negative) – which may be explained by the weak and negative relations between their bonds and those of US. Interestingly, Brazilian equity (1.13 percent) and long-term bonds yields (0.999 percent) offer higher returns compared to other emerging nations in this study.

5. CONCLUSION

The objective of this paper was to assess the impact of exchange rate volatility on equity returns and bond yields in BRICS countries during a period of time that differed from country to country owing to the availability of data. The study makes use of a multivariate GARCH-M model with BEKK specifications.

The estimations of results show that exchange rate volatility has a positive impact on ten-year bond yields in all BRICS countries except in South Africa, where the volatility of exchange rate has a negative impact. In addition, volatility to exchange rate positively influences equity returns in Brazil, India and South Africa, while the influence on Chinese and Russian equity returns is negative. These findings show that equity returns rise with the increase in exchange rate volatility, indicating that investors participating in most BRICS stock exchange markets seek high compensation for the existing risk.

Furthermore, the results on volatility spillovers between the equity returns, bond yields and foreign exchange markets show that the transmissions are from capital markets to the foreign exchange market in South Africa, while the volatility to currency markets influences capital markets in Russia. The results of the study give evidence of bidirectional volatility transmissions in Brazil and China. Surprisingly, in India, volatility is transmitted from foreign exchange markets to bond markets, while changes to equity influence the foreign exchange markets.

Furthermore, the findings of this study should inform policy makers on the possible impacts that volatility in foreign exchange markets have on the equity returns and bond yields markets particularly, and portfolio investment in general. It is worth noting that the BRICS group is becoming an attractive hub for portfolio investment, seeing the size of their portfolio investments on the world market increase significantly. It comes as no surprise that the five fastest growing nations host half of the net portfolio inflow to emerging countries. Therefore, these findings draw paths for improvement of policies implications that are specific to emerging economies (BRICS). Since it is shown that exchange rate volatility impact slightly negatively on equity returns and bond yields, authorities would better implement rigorous exchange rate policy in their respective countries.

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