Working Paper

IIMK/WPS/343/ECO/2019/19

AUGUST 2019

US Monetary Policy, Oil and Gold Prices:

Which has a greater impact on BRICS Stock Markets?

Md Gyasuddin Ansari[1]
Rudra Sensarma[2]

[1]Professor, Economics, Indian Institute of Management, Kozhikode, IIMK Campus PO, Kunnamangalam, Kozhikode, Kerala 673570, India; Email: rsensarma@iimk.ac.in, Phone Number (+91) 495 – 2809423

[2]Doctoral Student, Economics, Indian Institute of Management, Kozhikode, IIMK Campus PO, Kunnamangalam, Kozhikode, Kerala 673570, India - 673 571.

US Monetary Policy, Oil and Gold Prices: Which has a greater impact on BRICS Stock Markets?[1]

Abstract

This paper examines the effect of US monetary policy, oil price and gold price on stock indices of BRICS countries. Vector Auto Regression model is applied to study the stock indices of all BRICS countries as a group over the period 1996- 2018. We find that the Bombay Sensex responds positively to the Federal Funds Rate. The stock index of South Africa— FTSE JSE of Johannesburg— responds negatively to shocks in oil price while stock indices of Russia and Brazil— RTSI of Moscow and BVSP of Sao Paulo respectively— respond positively to gold price changes. We provide managerial and policy implications of these results.

JEL Classification

E52; E44; G10

Key Words

Monetary Policy; Stock Indices; Gold Price; Brent Crude; Federal Fund Rate

1. Introduction

This paper examines the impact of key global economic factors on stock markets of BRICS countries. The literature has studied a number of factors, both global and domestic, which impact domestic stock markets. Some of the domestic factors which influence the stock markets are fiscal policy, monetary policy, and other financial markets, while some of the

[1] We are grateful to Professor Paresh Narayan for his encouragement and insightful comments. We also acknowledge useful comments received from the participants of the Bank Indonesia and Asia-Pacific Applied Economics Association International Conference held in Bali, Indonesia during 30-31 August 2018.

global factors are leading economies' monetary policy (such as interest rates set by the Federal Reserve or the ECB), their financial markets and fiscal policies. Ross (1976) was the first researcher who established the relation between macroeconomic variables and return on investment. Roll and Ross (1980) established a more formal and well identified link between macroeconomic variables and returns. Since then, there have been a number of such studies for developed countries and some developing countries but there is no existing study that has examined the impact of global factors on the stock markets of BRICS economies (viz. Brazil, Russia, India, China, and South Africa) as a group.

Previous studies have examined the impact of US monetary policy, gold prices and oil prices on various international stock markets. For instance, Kim (2009) showed that, owing to the leadership role of the US markets, any effect of the Federal Fund Rate (FFR) on US markets also has a spillover effect in Asia-Pacific stock markets, which they refer to as the news impact. Wongswan (2009) studied the effects of FFR changes on stock markets in Asia, Europe and Latin America and offered two explanations for why such spillover effects happen. First, any change in FFR conveys information on future economic activity in the US which may affect the cash flows of companies in international markets. Second, changes in FFR may lead to changes in global interest rates that would affect the discount rates and hence equity prices in other countries. There are a few other papers which have examined the interrelationship between monetary policies of financially dominant economies and stock markets of dependent economies or groups of economies (see for example Cheng et al. 2010, Aloui and Hkiri 2014 and Chau et al 2014 for MENA and GCC; Hausman and Wongswan 2011 for a large panel of 49 countries).

Moving to the relationship between oil prices and international stock markets, studies have shown that given the significance of oil to the international economy, changes in oil prices have an effect on current and future real cash flows and therefore stock returns in international

markets (see Jones and Kaul, 1996; Park and Ratti, 2008 for studies on OECD and European markets). Basher and Sadorsky (2006) showed similar results for emerging stock markets and argued that the cash flows are affected both by supply side factors (higher oil prices raise the cost of doing business) and demand side factors (higher oil prices reduces the purchasing power of consumers thereby reducing demand in the economy). Studies have shown that the nature of response of stock markets to oil prices depends on whether the country is a net oil importer or exporter (Bhar and Nikolova 2009). A net oil exporter exhibits a positive response while a net oil importer responds negatively. Regional and global spillover of oil price and other global variables on stock markets can be found in various studies (see for example, Jouini 2013, Alotaibi and Mishra 2015 in MENA region; Basher et al 2012 for emerging markets proxied by the MSCI emerging stock market index).

There are a few studies which examine the interaction of gold prices and stock markets based on the premise that gold acts as a hedge as well as a safe haven (see Baur and McDermott, 2010; Arouri et al, 2015 for studies on emerging markets). Its role as a hedge comes from the tendency of gold prices to rise when values of other assets fall and the fact that this characteristic persists even in turbulent period makes gold a safe haven.

While the above papers have studied the impact of the three global macroeconomic variables on various international markets, ours is the first to analyze the impact of all three global variables together on BRICS stock markets as a group. The only study that comes close to ours is Mensi et al. (2014), who study the impact of US stock markets and global commodity prices on BRICS stock returns. However they do not study the impact of US monetary policy and use a quantile regression method. Instead we include US monetary policy (FFR) in our list of global factors and use a VAR approach that allows us to study the dynamic effects over time.

We choose to study BRICS markets as a group because of their rapidly rising importance in the global economy. BRICS is one of the largest groups of countries in the world comprising almost 40 percent of the world population. Their economic rise has been impressive e.g. from a share of 11 percent of world GDP in 1990, BRICS economies enjoyed a share of 32 percent of world GDP in 2018. All the BRICS countries are well integrated to the global economy and have benefitted from this integration. For instance India and China are closely linked with global supply chains while Brazil, South Africa and Russia have enjoyed the gains from exporting their natural resources. BRICS economies are also major consumers of commodities and international trade with the rest of the world as well as among BRICS countries has flourished in the last few decades. All these factors have made BRICS stock markets a favorable destination for global investments.

There are studies that show the increasing interconnectedness of BRICS stock markets (see Cheng and Glascock, 2006; Sharma et al, 2013; Dasgupta, 2014). These studies suggest that Asian stock markets exhibit co-movement both among themselves and with the US. Emerging markets are large in size and exhibit high volatility. There are a large number of companies which are listed in stock markets of these countries. Since these markets are well integrated globally, inflow and outflow of capital has speculative impact on stock prices and returns. Majority of the BRICS countries (except Russia) are oil importers. Despite having large oil reserves, Brazil imports some oil from Gulf countries. It imports light crude because refineries in Brazil are outdated and it is not feasible to process heavy oil[2]. Hence we can expect to find an impact of global crude prices on the BRICS stock markets.

Most of the emerging economies, including BRICS, are sensitive to FOMC decision and react to changes in the FFR. For example, an increase in FFR narrows the gap between return on

[2] Reuters Staff. Brazil says to export more oil in 2014 than it will import. Reuters, May 20, 2014.

investment in the US and emerging economies like BRICS. Consequently investors pull their money out by selling local currencies (of BRICS) and converting it into the dollar, which finally results in subdued domestic stock prices. Hence, an increase in FFR in US leads to outflow of investment and a decrease leads to inflow of investment in BRICS economies. India and China are among the largest importers of gold while South Africa is a gold exporter. Hence international gold price directly impacts these economies beyond its previously discussed role as a hedge and a safe haven. The above background creates a motivation to explore the impact of global macroeconomic factors on BRICS stock markets.

In this paper we analyse the impact of the US monetary policy, oil and gold prices, proxied by the FFR, the Brent crude price and gold price respectively, on stock markets of BRICS countries. We explore the varying response of the stock markets of BRICS to the abovementioned global macroeconomic variables. In particular we examine the following hypothesis about the BRICS stock markets. Do changes in global macroeconomic variables lead to any effects on BRICS stock markets? Which global variable(s) has a greater effect on BRICS stock markets?

Using a Vector Auto Regression (VAR) model we find that, transmission effect of US monetary policy to the indices of BRICS stock markets is not significant (with an exception of Bombay Sensex). However, oil price has an impact on FTSE JSE Johannesburg while RTSI Moscow and BVSP Sao Paulo respond to gold prices, in varying degrees. We also carry out some robustness checks such Generalized Response Function and Structural VAR analysis. The results are consistent across the estimation techniques we have used for the analysis.

Our paper contributes to the literature by analyzing the simultaneous impact of three important global factors on stock markets of BRICS countries. In this sense our study is more comprehensive in its choice of global factors than similar papers in the literature (Narayan and

Narayan 2012, Sum 2013, Sotoudeh and Worthington 2015 and Gupta and Sharma 2018). Second, we apply the VAR method in our analysis instead of the frequently used country-specific regressions or event studies. In any study involving macroeconomic time series data it is important to consider lagged responses that can be done through the VAR technique. Lagged response is considered because there exists a time gap between an action (e.g. FOMC decision) and its effects (e.g. movement in stock indices). This is consistent with the practice of many decision making authorities such as central banks and backed by empirical research (see Goodhart 2001). It appears that there is no study that has systematically analysed the dynamic effects of global factors on BRICS markets. Our paper is different from existing papers in terms of our choice of methodology (VAR), variables (three global factors) and sample (BRICS economies) which serve to contribute to the literature.

This paper is organized as follows. Section 2 outlines of data and descriptive statistics, section 3 methodology, section 4 presents the results and discussion. Finally, section 5 concludes.

2. Data and Descriptive Statistics

This study examines the impact of Federal Fund Rate (FFR), gold price and Brent crude price on five stock markets from BRICS countries, i.e. Brazil, Russia, India, China and South Africa.[3] We have used the FFR because it is the announcement of a change in the nominal rate which has greater effect on the stock markets than the real interest rates charged by the banks (see, for example, Thorbecke, 1997; Bomfim, 2003; Bjornland and Leitemo, 2009). We have taken one leading index of each country's major stock exchange. The indices taken for this study are SZSE Component Index (SZSE CI) of Shenzhen Stock Exchange, SENSEX of Bombay Stock Exchange, RTS Index (RTSI) of Moscow Stock Exchange, FTSE JSE Africa

[3] We do not include domestic macroeconomic variables in the model to avoid having a large number of variables in our model especially since the focus of the paper is on the impact of global factors on domestic stock markets.

Index (FTSE JSE) of Johannesburg Stock Exchange and BVSP of Sao Paulo Stock Exchange (B3).

The data taken for the study are monthly and span from January 1996 to December 2018. We chose the starting period as 1996 because of the following reasons. Most BRICS economies underwent extensive economic (including financial sector) and politico-economic reforms in the 1990s. For example, India opened up its economy to the world in 1991 thereby starting the integration with the world economy. Regime change in Brazil in the 1990s led to economic reforms which were successful in stabilizing the economy. In South Africa, apartheid rule came to an end in the early 1990s, which led to economic reforms and beginning of the integration of the economy to the global economy. For China too, 1990s marks the reform period, after decades of vacillation in the earlier decades. In 1992, after the collapse of the USSR, Russia joined the IMF and World Bank, making inroads into the global economy leading to many more reforms across the sectors of the economy. The RTS Index of Moscow Stock Exchange was launched in 1995 and proper data that were available for this index is from 1996. Hence for consistency we kept the starting period for all the markets in our sample as January 1996. The reason behind taking monthly data is that Federal Fund Rate changes are announced monthly so at this frequency all the data become comparable. London Metal Exchange sets the reference price for gold from where it is disseminated worldwide. Brent crude oil price is the price of the oil produced in oil fields of the North Sea. It is used as a reference price for almost all types of crude oil including oil produced by countries of the Middle East. It is used to price two-third of internationally traded crude oil. The Brent crude is traded at electronic Intercontinental Exchange (ICE). The FFR and oil price data are taken from the Federal Reserve Bank of St. Louis, USA, while the data for gold are taken from the World Gold Council. Stock indices data are taken from yahoo finance. Table A12 summarizes the sources of the data.

Table A1 shows a comparison of stock exchanges of the BRICS countries. As far as market cap and number of companies listed are concerned, Shenzhen Stock Exchange and Bombay Stock Exchange are leading with Shenzhen on number one spot and Bombay Stock Exchange a distant second. The Moscow, Sao Paulo and Johannesburg stock exchanges are relatively smaller as compared to Bombay and Shenzhen, though they are leading stock exchanges in their countries. We can observe from Table A1 that RTSI Moscow index return is the highest among BRICS nations in 2018. Some experts say that the surge in Russian stock market is primarily due to easing of previously tight monetary policy while others believe that it is low US interest rate that is responsible[4]. Index return for RTSI Moscow and BVSP Sao Paulo are the highest among the BRICS, while the other three fare relatively poorly, e.g. returns are almost negligible for Johannesburg.

Table A2 shows the descriptive statistics of the main variables. Average returns of the market indices and their volatility are compared. The stock indices of Brazil, China and South Africa realized higher gains than India and Russia realized during 1996- 2018. Gains in Brent crude are less as compared with gold. The stock indices of China, Russia, South Africa and Brazil are more volatile than that of India.

3. Methodology

3.1 Unit Root Test

Before we analyse the interrelationship between the variables, we use two traditional unit root tests i.e. Augmented Dickey- Fuller Test (ADF Test) and Phillips- Perron Test (PP Test) to test for the Stationarity of the time series data (see Table A3). In addition, we have also carried out unit root tests with one structural break (Perron, Table A4).[5] We use the following equation for the standard ADF test for unit root.

[4] https://www.rt.com/business/369508-russia-markets-index-top-global/

[5] We did not carry out unit root tests with two structural breaks (Narayan and Popp, 2010) as this test is recommended mainly for substantially long periods of time (3- 4 decades) but our time period is not that long.

$$y_t = \mu + \beta t + \alpha y_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + e_t \qquad \ldots\ldots\ldots (1)$$

Here $e_t \sim$ IID $(0, \sigma^2)$. The PP test uses a non- parametric method which controls for serial correlation of higher order. The null hypothesis is that the variable contains a unit root. Our variables include FFR, Brent Crude (price), Gold (price), SZSE CI, SENSEX, RTSI, FTSE JSE, and BVSP. We test all variables for unit roots, using their natural logarithm except FFR. To find the optimal lag length for the tests, we rely on Akaike Information Criterion (AIC), Hannan Quinn (HQ), Schwarz Criterion (SC), Likelihood Ratio (LR) and Final Prediction Error (FPE).

3.2 VAR Model

We have used the VAR methodology starting with an unrestricted VAR and later on a structural VAR. This technique treats all variables in the system as endogenous which allows unobserved individual heterogeneity. The VAR based analysis of monetary transmission mechanism has been applied extensively, following the break through by Sims (1980). Since then a number of studies such as Geske and Roll (1983), Fung and Kasumovich (1998), Sellin (2001), Bjornland and Leitemo (2009) etc. have applied VAR methods to study economies across regions. Similarly, there are papers that studied the response of stock markets to oil prices applying VAR methodology (see for instance, Kilian and Park, 2009; Maghyereh, 2006; Park and Ratti, 2008; Apergis and Miller, 2009). Similarly VAR has been applied to study the impact of gold price on stock markets (see for example Arouri et al, 2015; Mensi et al, 2014).

Figure A2 shows the movement of BRICS stock indices (in logarithm form) over the period of analysis. We observe that BRICS stock markets exhibit co-movement during this period as is also corroborated in the correlation matrix (Table A5). This suggests that there is interdependence among the BRICS stock indices which means it is appropriate to study them together in a VAR model.

We specify the first- order VAR as given below:

$$Z_{it} = \Gamma_0 + \Gamma_1 z_{it-1} + e_{it} \qquad \ldots\ldots\ldots (2)$$

Where Z_{it} is an eight variable vector which includes FFR, Brent Crude, Gold, SZSE CI, SENSEX, RTSI, FTSE JSE, BVSP.

We have ordered the variables based on decreasing order of exogeneity as is required under the Cholesky decomposition technique for identification of the VAR. It means the ordering is based on relative impact. Historically the impact of FFR has been greater on stock indices of these countries, so we have placed it first. Brent Crude price and gold price have comparatively less impact on these stock indices hence we place these variables after FFR. We order the stock indices considering opening timing of the stock markets. As per UTC standard, the opening of the stock markets are in the following order: Shenzhen Stock Exchange, China (01:30 hours), Bombay Stock Exchange, India (03:45 hours), Moscow Stock Exchange, Russia (07:00 hours), Johannesburg Stock Exchange, South Africa (07:00 hours) and Sao Paulo Stock Exchange, Brazil (13:00 hours). The logic behind this ordering based on opening timing is that, the stock markets which start trading earlier can have an impact on those that open later.

3.3 SVAR model

SVAR model can be used as a robustness check on the results from the VAR model as it allows an alternate way to identify the VAR. Unlike the standard VAR which uses Cholesky decomposition method, SVAR uses theoretically derived restriction (Amisano and Giannini, 1997). In this model, short-run exclusion restrictions (zero value) are put on the contemporaneous coefficients. Equations (4) and (5) show the structural and reduced form equations, respectively for the SVAR model.

3.3.1 Structural form

$$Bx_t = \Gamma_0 + \Gamma_1 x_{t-1} + \mathcal{E}_t \qquad \ldots\ldots\ldots (3)$$

3.3.2 Reduced Form

We get the reduced form after multiplying B^{-1} in the above structural form equation.

$$X_t = A_0 + A_1 x_{t-1} + e_t \qquad \ldots\ldots\ldots (4)$$

Where $A_0 = B^{-1}\Gamma_0$, $A_1 = B^{-1}\Gamma_1$ and $e_t = B^{-1}\varepsilon_t$

The details of the identification scheme we use are explained in section 5.2 where the SVAR results are also presented.

4. Results and Discussion

4.1 VAR Estimation

Initially we performed a series of tests to check the adequacy of the model to be used in the analysis. First we conducted the ADF and PP tests for stationarity applying both traditional approach as well as with one structural break (see Tables A3 and A4). All the variables (with an exception of SZSE CI, which is the stock index of Shenzhen Stock Exchange) are non-stationary at level but stationary at first difference. Next we tested for cointegration among the variables. The idea behind cointegration is that if a system of two or more time series are non-stationary at levels and have individual stochastic trends, then they may share common stochastic trends. In this case those series are said to be cointegrated. The cointegration test does not show conclusive results regarding the existence of cointegrating equations at the optimal lag length of 1. Trace Test shows there are no cointegrating equations while Max-Eigenvalue Test shows there may be one cointegrating equation. The results of the tests are given in Table A6. In the absence of conclusive evidence for cointegration, we proceed for estimating a VAR in first differences. We test for VAR stability (see Table A7 and Figure A1) and find favorable result to conduct VAR analysis as all roots lie inside the unit circle. In

addition, we also test for autocorrelation (correlation LM Tests) and the results do not show evidence for serial correlation beyond lag 1 (see Table A8).

Table A9 shows the results of the estimation of the VAR model. The analysis is based on lag order of 1 as suggested by information criteria (see Table A10). Based on the VAR estimates, we observe that lagged SZSE CI of Shenzhen is positively related to FFR at 1 per cent level of significance. The coefficient of lagged Bombay Sensex is statistically significant for FFR and Brent Crude at 5 per cent and 1 per cent level of significance, respectively. The coefficient of lagged FFR has a positive relationship with Bombay Sensex at 5 per cent level of significance (this is also confirmed in pairwise Granger Causality test that is not reported here to save space). We observe that RTSI is positively related to lagged Gold price and the result is significant at 1 per cent, which may be due to Russia being the third largest gold producer in the world and also an exporter of gold. Brent crude price is positively associated with RTSI Moscow which is because Russia is the world's largest oil producer and also an exporter. These results with respect to RTSI Moscow are also confirmed by pairwise Granger Causality tests (not reported here to save space).

FTSE JSE Johannesburg shows significant and positive association with Brent Crude price at 5 per cent level of significance. The pairwise Granger Causality test shows that both gold and oil prices are Granger caused by FTSE JSE Johannesburg. We observe from Table A9 that BVSP Sao Paulo does not show a statistically significant association with any global variables, however Granger Causality test shows that BVSP Sao Paulo does Granger cause oil and gold prices at 5 per cent level of significance. One possible reason for this surprising results— as there is reverse causality from indices to global variables— may be that it reflects the picking up of advanced signals by the stock market participants with respect to FFR, Gold and oil prices. This advanced signal causes anticipation of increase or decrease in stock markets' indices as global macro variables move.

4.2 Impulse Response Function Analysis

Figure A3 shows the Impulse Response Function results. It describes the effects of shocks to the variables in the VAR system and also provides the time paths of the effects of each shock. The results show the impulse responses generated from a one standard deviation of shocks to each variable over a 10- month time horizon, along with the 95 per cent standard error bands. We observe that Bombay Sensex shows a positive and fairly long run response to FFR (even though the response is statistically significant only in the second period). The response peaks at the end of the second month and gradually declines to zero in the ninth month. The positive impact of FFR on Bombay Sensex is a good sign for investors as it indicates the absence of semi-strong efficiency. This finding is however not consistent with the existing literature (see for example Chulia et al 2017, Mensi et al 2016 etc.) where the impact was seen to be largely negative. One possible reason for the positive response could be that an increase in FFR is a sign of an imminent recovery in the US economy which would boost optimism in the Indian markets due to the news spillover effect (see Wongswan, 2009). Further higher FFR would lead to capital outflows and a depreciation of the Indian currency that would give a boost to exports. Although Bombay Sensex responds positively to oil and gold price shocks as well but these responses are statistically insignificant. It is a surprising result because historically Indian stock markets are perceived to be sensitive to global commodity prices. The insignificant impact might be possibly explained by three reasons. First, the Sensex consists of 30 well established and large companies which have excellent capability to smoothen out any disturbances caused by global variables such as gold and oil prices. The second reason may be that in recent times India has been holding a sizable amount of forex reserve (currently around $400 billion), and this gives a macroeconomic cushion to cope with any contingency arising out of the movement in oil and gold prices. Finally, the Indian government has launched several schemes which have reduced the country's dependence on gold imports. Since import expenses

of gold are declining, it is possibly helping in reducing stock market fluctuations due to changes in the international gold price.

For Shenzhen's SZSE CI, all the three global variables (FFR, Brent Crude and Gold) have positive but insignificant impact. There could be a number of reasons for these insignificant impacts. China holds the largest forex reserves which may work as a cushion for the domestic markets from any external shocks. China has created strategic petroleum reserves, which works to ease out the effect of any supply shocks such as oil price movements. China is the largest producer of gold and therefore any external shocks may be immunized.

We observe that gold price shocks positively impact RTSI of Moscow. There is however no significant impact of FFR and Brent Crude on RTSI Moscow. The impact of FFR on RTSI of Moscow is insignificant possibly because of large forex reserve that the Russian central bank has accumulated which acts as a macroeconomic cushion against external shocks. Russia has protected its market during the financial crisis period using its oil revenues (see, for example, Mensi et al. 2014). This observation could also explain the non-existence of any impact of US monetary policy on the Russian stock market as well. Indeed, till 2014, oil prices were on an increasing trajectory which helped Russia to shore up oil revenues and accumulate huge forex reserves. Our lack of evidence for the impact of global shocks on most BRICS markets (with an exception of Bombay Sensex) is in line with prior research that shows that US economic policy has no impact on BRICS stock markets (Mensi et al. 2014).

The response of FTSE JSE of Johannesburg is quite volatile (moves from positive to negative and again positive) to shocks in Brent Crude. The impact peaks (negatively) in the second month and becomes positive subsequently and then declines to zero in the fourth month. This result is inconsistent with earlier studies such as Narayan and Sharma (2011), Elyasiani et al (2011), Smyth and Narayan (2018). The other two global variables, FFR and gold price, have no statistically significant impact on FTSE JSE of Johannesburg. The insignificant impact of

gold is not consistent with previous studies which found that both oil and gold have significant impact on stock markets in South Africa (see for example Morema and Bonga-Bonga 2018). South Africa is now no longer the largest producer of gold, and any negative consequence of higher gold prices may be outweighed by cheaper oil imports[6]. The insignificant impact of FFR on FTSE JSE is not in consonance with previous literature (see for example Bowman et al 2015) and this can be explained by low net external liability, stable FDI inflows, Rand dominated private and public sector debt, relatively small and liquid financial market and adequate forex reserve (BIS Paper 2014).

Finally we find that BVSP Sao Paulo exhibits a positive response to shocks in gold price. The impact is not for too long though as it peaks in the third month and declines to zero in the fifth month. The results for RTSI Moscow and BVSP Sao Paulo are similar to the existing studies. Bouri et al (2018) and Mensi et al (2014) found similar positive impact of gold price on stock indices of Russia and Brazil. Similar to RTSI Moscow, BVSP Sao Paulo shows no response to Brent Crude and FFR. Brazil has the second largest oil reserves after Venezuela in South America, hence it is a major player in the oil market and a price maker than taker. This position of Brazil may be the reason why there is no impact of Brent crude on BVSP Sao Paulo. Brazil has an adequate level of forex reserve[7] and the Central Bank of Brazil often uses currency swaps to hedge its currency from external shocks.

We observe that individually, with an exception of Bombay Sensex, no other stock indices respond to FFR. However RTSI Moscow significantly responds to Gold, FTSE JSE Johannesburg significantly responds to Brent Crude and BVSP Sao Paulo shows significance response to Gold. Majority of the existing studies have reported an impact of FFR on BRICS stock markets (Li et al. 2010; Mallick and Sousa 2013). The positive response of RTSI Moscow

[6] https://www.cnbc.com/id/100667915
[7] https://www.ft.com/content/7b00dbe4-6ddf-11e8-92d3-6c13e5c92914

and BVSP Sao Paulo to gold price may be attributed to the fact that both Russia and Brazil are gold exporters. However FTSE JSE of Johannesburg does not respond to gold price even though South Africa is an exporter. This might be ascribed to the declining exports of gold from South Africa in recent years.

Similarly Bombay Sensex and SZSE CI of Shenzhen do not respond to the gold price shocks even though India is one of the largest importers (among the top 5 countries) and China is the largest producer. In the case of the former, government restriction on imports and programs to reduce imports may be responsible while in the case of the latter, despite being the largest producer of gold, export of gold is not allowed which might explain the lack of response of stock markets to gold prices.

4.3 Variance Decomposition Analysis

Table A11 shows the forecast error variance decomposition based on the unrestricted VAR. It presents the relative importance of each random innovation in the variations in the variables in the VAR. Here we examine relative variation in stock indices of BRICS resulting from global variables i.e. FFR, Brent Crude and Gold.

Shenzhen's SZSE CI index has the largest variation in its index due to FFR. After initial periods the contribution of these global variables in the variation becomes constant. Brent Crude causes slightly less variation than FFR. Gold price has minimal contribution to the variation in this index. We observe that Bombay Sensex derives largest portion of variation in its index from FFR followed by gold price and Brent crude price. And as the time passes the contribution of FFR in the variation in stock index slightly increases, however variations due to Brent Crude and Gold Prices remain constant. For RTSI Moscow gold price contributes to the largest variation. The variation in the index due to gold is stable after the initial period. The variations caused by Brent crude price and FFR have been relatively lower. In case of the former, after

an initial increase it has become constant while in the case of the latter it has been increasing over time.

The largest variation in FTSE JSE Johannesburg comes from Brent crude price. The variation has been consistent after an initial surge. The two other global variables, FFR and gold price, have relatively little role in the variation of the index. The variations in the index of Sao Paulo, BVSP mainly comes from gold price and FFR followed by Brent crude price, although minimal. The contribution of Brent Crude and Gold in the variation in BVSP index become constant after the initial months, however variations due to FFR have been increasing.

5. Robustness checks

5.1 Generalized Impulse Response and Variance Decomposition

IRFs obtained from Cholesky Decomposition are usually criticized on grounds of the results being dependent on the choice of ordering of the variables. Generalized Impulse Responses are, however, known to be invariant to the ordering of variables. This serves as a robustness check to the earlier impulse response results so that there is no variation in responses as orderings of variables are changed. The findings from the Generalized Impulse Response Functions are the same as from the earlier IRFs by Cholesky Decomposition Method.

We observe, here too, that with an exception of Bombay Sensex, no other stock indices respond to FFR; however RTSI Moscow, FTSE JSE Johannesburg and BVSP Sao Paulo responds to gold price, Brent crude and gold price respectively. The direction of impulse response remains the same for all the variables. Generalized Variance decomposition results are also similar to the previously reported Variance decomposition results (output not reported to save space).

5.2 SVAR Model Identification

As a robustness check of the VAR results, we repeat the previous VAR exercise but now we impose theoretically derived restrictions to identify the VAR. This follows the AB model of Amisano and Giannini (1997).

We use the following ordering for identification of the model.

Series: DFFR, DBrent Crude, DGold DSZSE, DSENSEX, DRTSI, DTFSE JSE, DBVSP.

We have applied restrictions on the variables based on theory, as we examine the impact of US monetary policy, oil and gold prices on BRICS stock markets. Here we restrict variables to identify the VAR to limit interactions among them. After the restrictions, we maintain that each index of BRICS stock markets is influenced separately by FFR, oil and gold prices. We have assumed FFR, oil and gold prices to be exogenous implying that these variables are not contemporaneously linked to the stock markets in the BRICS economies. Any changes in FFR, oil and gold prices do not happen keeping in view the stock indices in BRICS countries.

$$\mathbf{A} \qquad \mathbf{u} \qquad = \qquad \mathbf{e}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{11} & a_{12} & a_{13} & 1 & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & a_{23} & 0 & 1 & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 & 1 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 0 & 0 & 0 & 1 & 0 \\ a_{51} & a_{52} & a_{53} & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_t^{DFFR} \\ u_t^{DBrent\ Crude} \\ u_t^{DGold} \\ u_t^{DSZSE} \\ u_t^{DSENSEX} \\ u_t^{DRTSI} \\ u_t^{DFTSE\ JSE} \\ u_t^{DBVSP} \end{bmatrix} = \begin{bmatrix} e_t^{DFFR} \\ e_t^{DBrent\ Crude} \\ e_t^{DGold} \\ e_t^{DSZSE} \\ e_t^{DSENSEX} \\ e_t^{DRTSI} \\ e_t^{DFTSE\ JSE} \\ e_t^{DBVSP} \end{bmatrix} \ldots (5)$$

Also, the impact of these global variables do not take place contemporaneously. For example, change in FFR by the US Federal Reserve may not have an impact on stock indices immediately but after sometime, say one period later. Similar is the case with oil and gold prices as well.

This is also the reason why we have taken lagged variables for the analysis. Our SVAR model is just-identified as we need 28 restrictions— based on the formula $(n^2 - n)/2$, where n is the number of variables— and we have imposed the same number of restrictions (see equation 3).

5.3 Impulse Response Function and Variance Decomposition Analysis (Based on SVAR)

The dynamic responses of stock indices and variance decomposition for Structural VAR analysis are similar to those in the unrestricted VAR analysis. We observe, here too, that with an exception of Bombay Sensex, no other stock indices respond to FFR; however RTSI Moscow, FTSE JSE Johannesburg and BVSP Sao Paulo responds to gold price, Brent crude price and gold price respectively. The direction of impulse response remains the same for all variables. Variance decomposition based on Structural Vector Autoregression (SVAR) is the same as in case of the unrestricted VAR. Bombay Sensex derives the largest proportion of variation in its index from FFR followed by gold price and Brent crude price. For other indices, here we too observe that the result of structural VAR is almost similar to unrestricted VAR.

6. Conclusion

In this paper we studied the reaction of stock indices of BRICS markets to shocks in US monetary policy, Brent crude price and gold price. The transmission effect of US monetary policy on these stock indices seem to be insignificant with an exception of Bombay Sensex, which is not in consonance with previous studies. However gold and crude prices impact indices of BRICS stock markets except Bombay Sensex. But the impact is not uniform across these stock markets.

The results of this paper have many policy implications. The stylized fact that US monetary policy has an impact on BRICS stock markets, should be given a second thought. As far as the US monetary policy (FFR) is concerned, the policy makers may not be cautious while considering the impact of FFR while devising policies. For investors and traders, innovation in

FFR may work as a cue for movement in stock indices so that they can be cautious while investing and trading. Similar implications regarding Brent Crude and Gold Prices can be drawn upon. As we have found that RTSI Moscow and BVSP Sao Paulo respond positively to gold price, hence an increase in gold price may lead to an increase in the returns on these indices. It is imperative for policy makers to be proactive in responding to the upward or downward change in the price of Brent crude. Policy makers must be cautious because South Africa is an oil importer. This volatility is of very much significance to investors and traders as they can sense the direction in which these indices might be heading.

Since the BRICS stock indices (with an exception of Bombay Sensex) do not react strongly to US monetary policy, therefore investors do not need to track changes in the Fed's policy decisions for their investment strategies, but market participants need to be paying heed to FOMC meetings and its announcements, so that they can get positive benefits of changes in FFR. However, some of the BRICS stock indices, such as RTSI Moscow and BVSP Sao Paulo respond to changes in Gold price which suggests that investors can use the gold market as a source of advance information for movements in the stock market. Investors in SZSE CI of Shenzhen may not need to track any of these global variables to predict movement in their index. FTSE JSE of Johannesburg has vacillating response to shocks in Brent crude, which suggests that investors should be very careful while observing Brent crude price as a source of advance information for movements in this stock market.

This study has some limitations. It is based on one leading index of a major stock exchange from BRICS stock markets, so its findings are not applicable to the other indices. Essentially ours is an index based study rather than stock markets based (although we have used the same notation). The sample includes around 276 observations within a span of 23 years that can be increased for analyzing long run relationships. Finally, the indices used in study are quite heterogenous in terms of magnitude and capitalization. Stock exchanges of Johannesburg,

Moscow and Sao Paulo do not have significant trading volumes as in the cases of Bombay and Shenzhen. In future we can separately study groups of countries depending on their economic characteristics. For example, Brazil and Russia, being oil exporters, can be studied separately from India, China and South Africa who are oil importers. Similar grouping can be designed with respect to gold as well.

References

Alotaibi, A. R., & Mishra, A. V. (2015). Global and regional volatility spillovers to GCC stock markets. *Economic Modelling, 45,* 38-49

Aloui, C., & Hkiri, B. (2014). Co-movements of GCC emerging stock markets: New evidence from wavelet coherence analysis. *Economic Modelling*, *36,* 421-431.

Amisano, G., & Giannini, C. (1997). From var models to structural var models. In *Topics in Structural VAR Econometrics* (pp. 1-28). Springer, Berlin, Heidelberg.

Apergis, N., & Miller, S. M. (2009). Do structural oil-market shocks affect stock prices? *Energy Economics*, *31*(4), 569-575.

Arouri, M. E. H., Lahiani, A., & Nguyen, D. K. (2015). World gold prices and stock returns in China: insights for hedging and diversification strategies. *Economic Modelling*, *44,* 273-282.

Bank, S. A. R. (2014). The international transmission of monetary policy-lessons learnt in South Africa. *BIS Papers chapters,* 78, 321-331.

Basher, S. A., & Sadorsky, P. (2006). Oil price risk and emerging stock markets. *Global finance journal, 17*(2), 224-251.

Basher, S. A., Haug, A. A., & Sadorsky, P. (2012). Oil prices, exchange rates and emerging stock markets. *Energy Economics, 34*(1), 227-240.

Baur, D. G., & McDermott, T. K. (2010). Is gold a safe haven? International evidence. *Journal of Banking & Finance, 34*(8), 1886-1898.

Bhar, R., & Nikolova, B. (2009). Oil prices and equity returns in the BRIC countries. *The World Economy, 32*(7), 1036-1054.

Bjornland, H. C., & Leitemo, K. (2009). Identifying the interdependence between US monetary policy and the stock market. *Journal of Monetary Economics, 56*(2), 275-282

Bomfim, A. N. (2003). Pre-announcement effects, news effects, and volatility: Monetary policy and the stock market. *Journal of Banking & Finance, 27*(1), 133-151

Bouri, E., Gupta, R., Hosseini, S., & Lau, C. K. M. (2018). Does global fear predict fear in BRICS stock markets? Evidence from a Bayesian Graphical Structural VAR model. *Emerging Markets Review, 34*, 124-142.

Bowman, D., Londono, J. M., & Sapriza, H. (2015). US unconventional monetary policy and transmission to emerging market economies. *Journal of International Money and Finance, 55*, 27-59.

Chau, F., Deesomsak, R., & Wang, J. (2014). Political uncertainty and stock market volatility in the Middle East and North African (MENA) countries. *Journal of International Financial Markets, Institutions and Money, 28*, 1-19

Cheng, A. R., Jahan-Parvar, M. R., & Rothman, P. (2010). An empirical investigation of stock market behavior in the Middle East and North Africa. *Journal of Empirical Finance, 17*(3), 413-427

Cheng, H., & Glascock, J. L. (2006). Stock market linkages before and after the Asian financial crisis: evidence from three greater China economic area stock markets and the US. *Review of Pacific Basin Financial Markets and Policies, 9*(02), 297-315.

Chulia, H., Gupta, R., Uribe, J. M., & Wohar, M. E. (2017). Impact of US uncertainties on emerging and mature markets: Evidence from a quantile-vector autoregressive approach. *Journal of International Financial Markets, Institutions and Money, 48*, 178-191.

Dasgupta, R. (2014). Integration and dynamic linkages of the Indian stock market with bric-an empirical study. *Asian Economic and Financial Review, 4*(6), 715.

Elyasiani, E., Mansur, I., & Odusami, B. (2011). Oil price shocks and industry stock returns. *Energy Economics, 33*(5), 966-974.

Fung, B. S. C., & Kasumovich, M. (1998). Monetary shocks in the G-6 countries: is there a puzzle? *Journal of Monetary Economics, 42*(3), 575-592.

Geske, R., & Roll, R. (1983). The fiscal and monetary linkage between stock returns and inflation. *The journal of Finance, 38*(1), 1-33.

Goodhart, C. A. (2001). Monetary transmission lags and the formulation of the policy decision on interest rates. In *Challenges for Central Banking* (pp. 205-228). Springer, Boston, MA.

Gupta, V., & Sharma, P. (2018). The impact of oil prices on stock prices and other macroeconomic variables in India: pre-and post-2008 crises. *OPEC Energy Review, 42*(3), 212-223.

Hausman, J., & Wongswan, J. (2011). Global asset prices and FOMC announcements. *Journal of International Money and Finance, 30*(3), 547-571

Jones, C. M., & Kaul, G. (1996). Oil and the stock markets. *The journal of Finance, 51*(2), 463-491.

Jouini, J. (2013). Stock markets in GCC countries and global factors: A further investigation. *Economic Modelling, 31*, 80-86

Kilian, L., & Park, C. (2009). The impact of oil price shocks on the US stock market. *International Economic Review, 50*(4), 1267-1287.

Kim, S. J. (2009). The spillover effects of target interest rate news from the US Fed and the European Central Bank on the Asia-Pacific stock markets. *Journal of International Financial Markets, Institutions and Money, 19*(3), 415-431.

Li, Y. D., İşcan, T. B., & Xu, K. (2010). The impact of monetary policy shocks on stock prices: Evidence from Canada and the United States. *Journal of International Money and Finance, 29*(5), 876-896

Maghyereh, A. (2006). Oil price shocks and emerging stock markets: A generalized VAR approach. In Global Stock Markets and Portfolio Management (pp. 55-68). Palgrave Macmillan, London.

Mallick, S. K., & Sousa, R. M. (2013). Commodity prices, inflationary pressures, and monetary policy: evidence from BRICS economies. *Open Economies Review, 24*(4), 677-694.

Mensi, W., Hammoudeh, S., Reboredo, J. C., & Nguyen, D. K. (2014). Do global factors impact BRICS stock markets? A quantile regression approach. *Emerging Markets Review, 19*, 1-17.

Mensi, W., Hammoudeh, S., Yoon, S. M., & Nguyen, D. K. (2016). Asymmetric linkages between BRICS stock returns and country risk ratings: Evidence from dynamic panel threshold models. *Review of International Economics, 24*(1), 1-19.

Morema, K., & Bonga-Bonga, L. (2018). The impact of oil and gold price fluctuations on the South African equity market: volatility spillovers and implications for portfolio management.

Narayan, P. K., & Popp, S. (2010). A new unit root test with two structural breaks in level and slope at unknown time. *Journal of Applied Statistics, 37*(9), 1425-1438.

Narayan, P. K., & Sharma, S. S. (2011). New evidence on oil price and firm returns. *Journal of Banking & Finance, 35*(12), 3253-3262.

Narayan, S., & Narayan, P. K. (2012). Do US macroeconomic conditions affect Asian stock markets? *Journal of Asian Economics, 23*(6), 669-679.

Park, J., & Ratti, R. A. (2008). Oil price shocks and stock markets in the US and 13 European countries. *Energy Economics, 30*(5), 2587-2608.

Roll, R., & Ross, S. A. (1980). An empirical investigation of the arbitrage pricing theory. *The Journal of Finance, 35*(5), 1073-1103.

Ross, S. A. (1976). The arbitrage pricing of capital asset pricing1. *Journal of Economic Theory, 13*, 341-360.

Sellin, P. (2001). Monetary policy and the stock market: theory and empirical evidence. *Journal of Economic Surveys, 15*(4), 491-541.

Sharma, G. D., Mahendru, M., & Singh, S. (2013). Are the stock exchanges of emerging economies inter-linked: Evidence from BRICS? *Indian Journal of Finance, 7(1).*

Sims, C. A. (1980). Macroeconomics and reality. *Econometrica: Journal of the Econometric Society*, 1-48.

Smyth, R., & Narayan, P. K. (2018). What do we know about oil prices and stock returns? *International Review of Financial Analysis, 57*, 148-156.

Sotoudeh, M. A., & Worthington, A. C. (2015). Macroeconomy and Financial Market Effects of Oil Price Changes: A Comparison of Large Net Oil-Producer and Oil-Consumer Countries. *Economic Papers: A Journal of Applied Economics and Policy, 34*(1-2), 11-22.

Sum, V. (2013). The ASEAN stock market performance and economic policy uncertainty in the United States. *Economic Papers: A Journal of Applied Economics and Policy, 32*(4), 512-521.

Thorbecke, W. (1997). On stock market returns and monetary policy. *The Journal of Finance, 52*(2), 635-654.

Wongswan, J. (2009). The response of global equity indexes to US monetary policy announcements. *Journal of International Money and Finance, 28*(2), 344-365

Appendix: A

Table A1
Comparison among BRICS' stock markets

Name of the Stock Exchange	Companies Listed*	Market Cap ($B)*	Index Return (percentage)**
Shenzhen	2134	2405.45	1.17
Bombay	5066	2083.48	1.15
Moscow	225	576.11	1.86
Johannesburg	360	865.32	1.00
Sao Paulo	339	916.82	1.38

Source: * As on Dec 2018. ** Average return for Indices taken for the study (1996- 2018), calculated by the authors.

Table A2
Descriptive Statistics: January 1996 to December 2018

Index	Mean	Median	Maximum	Minimum	S. D.	Jarque- Bera	P- Value
FFR	2.3742	1.6950	6.5400	0.0700	2.2291	33.3680	0.0000
BRENT CRUDE	3.8331	3.9472	4.8882	2.2848	0.6649	15.4124	0.0004
GOLD	6.4943	6.5089	7.4797	5.5454	0.6558	30.9318	0.0000
SENSEX	8.7289	8.8994	9.8797	6.9189	0.5888	11.6260	0.0029
SZSE CI	9.2117	9.4688	10.562	7.9411	0.8479	27.8463	0.0000
RTSI	6.4906	6.8342	7.8078	3.7798	0.9446	33.6149	0.0000
FTSE JSE	9.8655	10.0455	10.9983	8.4297	0.7989	25.9316	0.0000
BVSP	10.3007	10.6539	11.4020	8.5081	0.8043	27.8300	0.0000

All variables, except FFR, are in log form. The data series is noted in column 1 FFR, BRENT CRUDE and GOLD stand for the Federal Fund Rate, Price of Brent crude per barrel and Price of gold per ounce respectively. SZSE, SENSEX, RTSI, FTSE JSE and BVSP represent indices of the Shenzhen Stock Exchange, the Bombay Stock Exchange, the Moscow Stock Exchange, the Johannesburg Stock Exchange and the Sao Paulo Stock Exchange (B3) respectively. We report mean, median, maximum, minimum, standard deviation, Jarque-Bera and P-value.

Table A3
Unit root test without structural breaks (ADF and PP) (January 1996 to December 2018)

Variables	Levels				First difference			
	ADF	Lags	PP	Lags	ADF	Lags	PP	Lags
Intercept only in the regression								
FFR	-1.483	1	-1.793	12	-7.658*	0	-7.703*	5
Brent Crude	-1.760	1	-1.710	4	-13.292*	0	-13.291*	1
Gold	-0.298	0	-0.362	6	-14.548*	0	-14.547*	5
SZSE CI	-3.143**	0	-3.142**	10	-14.517*	0	-15.204*	9
SENSEX	-0.599	0	-0.652	4	-16.064*	0	-16.093*	4
RTSI	-2.349	1	-2.367	6	-13.298*	0	-13.383*	5
FTSE JSE	-0.783	1	-0.705	20	-20.025*	0	-20.392*	12
BVSP	-1.726	0	-1.726	6	-16.037*	0	-16.034*	6
Intercept and trend in the regression								
FFR	-1.458	1	-1.758	12	-7.680*	0	-7.734*	5
Brent Crude	-1.891	1	-1.819	4	-13.298*	0	-13.298*	1
Gold	-1.479	0	-1.598	7	-14.529*	0	-14.527*	5
SZSE CI	-2.693	0	-3.183**	10	-14.654*	0	-15.315*	9
SENSEX	-2.242	0	-2.523	6	-16.038*	0	-16.068*	4
RTSI	-2.323	1	-2.370	7	-13.345*	0	-13.397	4
FTSE JSE	-2.413	1	-2.819	8	-19.993*	0	-20.362	12
BVSP	-2.315	0	-2.387	3	-16.054*	0	-16.047	7

All variables are in natural logs except FFR. *Significant at 1 percent level. ** Significant at 5 percent level.

Table A4
Unit root test with structural breaks (Perron) (January 1996 to December 2018)

Variables	Levels			First –difference		
	t_α ##	Lags	T_B $$	t_α	Lags	T_B
Intercept only in the regression						
FFR	-3.185	1	2000M11	-8.960*	0	2008M02
Brent Crude	-2.213	1	2003M09	-13.795*	0	2008M10
Gold	-3.635	0	2005M07	-15.496*	0	1999M10
SZSE CI	-5.763*	0	2005M11	-15.780*	0	1996M11
SENSEX	-3.179	0	2003M04	-16.901*	0	2008M10
RTSI	-3.848	1	2001M08	-14.410*	0	1998M07
FTSE JSE	-2.926	1	2003M04	-20.894*	0	1998M08
BVSP	-3.912	0	2003M02	-16.813*	0	1998M08
Intercept and trend in the regression						
FFR	-2.445	1	2000M11	-8.910*	0	2008M02
Brent Crude	-4.373	1	2014M07	-13.756*	0	2008M10
Gold	-3.419	0	2005M07	-15.842*	0	2011M08
SZSE CI	-5.935*	2	2006M09	-15.774*	0	1996M11
SENSEX	-3.665	0	2005M04	-16.870*	0	2008M10
RTSI	-3.618	1	2003M02	-14.562*	0	1998M07
FTSE JSE	-4.951	0	2005M04	-20.969*	0	1998M08
BVSP	-3.924	0	2003M07	-16.841*	0	1998M08

All variables are in natural logs except FFR. *Significant at 1 percent level. The lag selection is based on SIC criteria. ## t- Statistics and $$ Break date.

Table A5
Correlation Matrix

Correlation t- statistics probability	FFR	Brent Crude	Gold	SZSE CI	SENSEX	RTSI	FTSE JSE	BVSP
FFR	1.000							
Brent Crude	-0.609 -12.735 0.000	1.000						
Gold	-0.744 -18.486 0.000	0.851 26.927 0.000	1.000					
SZSE CI	-0.520 -10.082 0.000	0.707 16.564 0.000	0.815 23.311 0.000	1.000				
SENSEX	-0.622 -13.155 0.000	0.808 22.771 0.000	0.933 43.174 0.000	0.847 26.392 0.000	1.000			
RTSI	-0.582 -11.848 0.000	0.895 33.221 0.000	0.801 22.152 0.000	0.729 17.640 0.000	0.799 22.068 0.000	1.000		
FTSE JSE	-0.690 -15.808 0.000	0.823 24.041 0.000	0.929 41.767 0.000	0.820 23.728 0.000	0.978 77.672 0.000	0.814 23.235 0.000	1.000	
BVSP	-0.640 -13.798 0.000	0.887 31.927 0.000	0.896 33.400 0.000	0.856 27.462 0.000	0.944 47.518 0.000	0.888 31.989 0.000	0.936 44.033 0.000	1.000

All variables, except FFR, are in log form and level. The table reports correlation coefficient, t statistics and p value. We observe high degree of correlation among variables.

Table A6
Johansen Cointegration Test[a]

Null hypothesis about rank r	Trace Test[*]			Maximum Eigenvalue[#]		
	Trace Statistics	Critical value (at 5%)	Prob.[**]	Max Statistics	Critical value (at 5%)	Prob.[**]
r = 0	158.264	159.529	0.058	54.866	54.362	0.027
r ≤ 1	103.398	125.615	0.493	32.956	46.231	0.594
r ≤ 2	70.442	95.753	0.707	30.287	40.077	0.405
r ≤ 3	40.155	69.818	0.945	18.944	33.876	0.825
r ≤ 4	21.210	47.856	0.982	10.707	27.584	0.972
r ≤ 5	10.503	29.797	0.971	7.596	21.131	0.926
r ≤ 6	2.906	15.494	0.970	2.341	14.264	0.980
r ≤ 7	0.565	3.841	0.452	0.565	3.841	0.452

[*]Trace test indicates no cointegration at 0.05 level. [#]Max- eigenvalue test indicates one cointegrating equation at 0.05 level. [**] Mackinnon- Haug- Michelis (1999) p- values. [a] Series: DFFR, DBrent Crude, DGold, DSZSE CI, DSENSEX, DRTSI, DFTSE JSE, DBVSP.

Table A7
VAR Stability Test

Root	Modulus
0.661	0.661
0.364	0.364
-0.266	0.266
-0.088 -0.248	0.263
-0.088 +0.248	0.263
0.136	0.136
-0.043	0.043
-0.023	0.023

No root lies outside the unit circle.
VAR satisfies the stability condition.

Table A8
VAR Residual serial Correlation LM Tests

Lag	LRE stat	Prob.	Rao F stat	Prob.
1	130.963	0.0000	2.094	0.0000
2	90.005	0.0178	1.419	0.0178
3	71.511	0.2426	1.120	0.2429
4	69.042	0.3110	1.081	0.3113
5	60.433	0.6034	0.943	0.6037

Observation: There is no serial correlation after one lag.

Table A9

VAR Result: January 1996 to December 2018

	DFFR	DBrent Crude	DGold	DSZSE	DSENSEX	DRTSI	DFTSE JSE	DBVSP
DFFR (-1)	0.633***	0.050	-0.002	-0.018	0.058**	-0.009	0.019	0.017
	(0.046)	(0.033)	(0.014)	(0.036)	(0.024)	(0.050)	(0.021)	(0.024)
	[13.566]	[1.509]	[-0.181]	[0.511]	[2.428]	[-0.197]	[0.917]	[0.681]
DBrent Crude (-1)	0.030	0.122**	0.012	-0.080	-0.076*	0.080	-0.128***	-0.070
	(0.083)	(0.059)	(0.025)	(0.065)	(0.043)	(0.090)	(0.038)	(0.044)
	[0.371)	[2.041]	[0.474]	[-1.232]	[-1.768]	[0.894]	[-3.387]	[-1.571]
DGold (-1)	-0.327*	0.290**	0.109*	0.054	0.099	0.586***	0.103	0.126
	(0.197)	(0.141)	(0.061)	(0.155)	(0.102)	(0.213)	(0.090)	(0.105)
	[-1.662]	[2.045]	[1.793]	[0.353]	[0.970]	[2.750]	(1.148]	[1.199]
DSZSE (-1)	0.130*	0.011	0.017	0.097	0.128***	0.092	0.053	0.095**
	(0.179)	(0.057)	(0.024)	(0.062)	(0.041)	(0.085)	(0.036)	(0.042)
	[1.647]	[0.202]	0.721	[1.555]	[3.144]	[1.073]	[1.471]	[2.243]
DSENSEX (-1)	0.270**	0.270***	0.018	0.085	-0.045	0.268**	0.106**	0.082
	(0.123)	(0.088)	(0.038)	(0.097)	(0.063)	(0.133)	(0.056)	(0.066)
	[2.188]	[3.050]	[0.471]	[0.876]	[-0.716]	[2.007]	[1.894]	[1.244]
DRTSI (-1)	-0.078	0.081**	-0.006	0.069	0.176***	0.209***	0.263***	0.410***
	(0.057)	(0.041)	(0.017)	(0.045)	(0.029)	(0.062)	(0.026)	(0.030)
	[1.353]	[1.951]	[-0.388]	[1.523]	[5.885]	[3.350]	[9.952]	[13.253]
DFTSE JSE (-1)	0.060	0.203**	0.027	0.048	0.049	0.117	-0.286***	-0.028
	(0.138)	(0.099)	(0.042)	(0.109)	(0.071)	(0.149)	(0.063)	(0.074)
	[0.438]	[2.042)	[0.633]	[0.445]	[0.684]	[0.782]	[-4.524]	[-0.383]
DBVSP (-1)	-0.031	-0.104	0.043	0.055	-0.013	-0.317**	-0.023	-0.189***
	(0.115)	(0.082)	(0.035)	(0.090)	(0.059)	(0.124)	(0.052)	(0.061)
	[-0.275]	[-1.266]	[1.212]	[0.615]	[-0.225]	[-2.549]	[-0.455]	[-3.069]
C	-0.004	-0.000	0.002	0.004	0.006*	0.003	0.006**	0.007*
	(0.007)	(0.005)	(0.002)	(0.005)	(0.003)	(0.007)	(0.003)	(0.003)
	[-0.621]	[-0.140]	[1.177]	[0.758]	[1.768]	[0.491]	[1.979]	[1.798]
R Squared	0.458	0.147	0.041	0.046	0.203	0.107	0.353	0.440

Adj. R Squared	0.442	0.122	0.012	0.018	0.179	0.080	0.334	0.423
F Statistics	28.076	5.752	1.433	1.629	8.440	3.978	18.151	26.060
S E Equation	0.119	0.085	0.036	0.093	0.061	0.129	0.054	0.063
Log Likelihood	198.135	288.629	519.636	263.909	387.184	176.681	412.945	369.568

Standard Error in ( ) and t- Statistics in [ ]. All variables, except FFR, are in log form and at first difference. The data series is noted in row 1. *, ** and *** significant at 10 percent, 5 percent, 1 percent respectively. DFFR, DBRENT CRUDE and DGOLD stand for the Federal Fund Rate, Price of Brent crude per barrel and Price of gold per ounce respectively. DSZSE, DSENSEX, DRTSI, DFTSE JSE and DBVSP represent indices of the Shenzhen Stock Exchange, the Bombay Stock Exchange, the Moscow Stock Exchange, the Johannesburg Stock Exchange and the Sao Paulo Stock Exchange (B3) respectively. We report R Squared, Adjusted R Squared, F Statistics, Standard Error Equation and log likelihood.

Table A10
Lag Length selection for VAR*

Information Criteria	Optimal Lag	Lag Chosen
AIC	1	1
HQ	1	Going by majority of information criteria.
SC	1	
LR	7	
FPE	1	

* Series: DFFR, DBrent Crude, DGold, DSZSE CI, DSENSEX, DRTSI, DFTSE JSE, DBVSP. LR: Sequential modified LR Statistics, FPE: Final Prediction Error, AIC: Akaike Information Criterion, HQ: Hannan-Quin Information Criterion, SC: Schwartz Information Criterion.

Table A11
Variance Decomposition (VAR)

Period	FFR shock	Brent Crude shock	Gold shock	SZSE CI shock	SENSEX shock	RTSI shock	FTSE JSE shock	BVSP Shock
Response of SZSE								
1	0.551	0.298	0.043	99.108	0.000	0.000	0.000	0.000
2	0.650	0.555	0.124	96.818	0.616	0.992	0.134	0.106
3	0.703	0.574	0.153	96.063	0.616	1.626	0.143	0.117
4	0.717	0.576	0.165	96.022	0.623	1.627	0.145	0.121
5	0.726	0.576	0.165	96.011	0.625	1.628	0.145	0.121
6	0.729	0.576	0.165	96.007	0.625	1.628	0.145	0.121
7	0.731	0.576	0.165	96.005	0.625	1.628	0.145	0.121
8	0.731	0.576	0.165	96.005	0.625	1.628	0.145	0.121
9	0.732	0.576	0.165	96.004	0.625	1.628	0.145	0.121
10	0.732	0.576	0.165	96.004	0.625	1.628	0.145	0.121
Response of Sensex								
1	1.100	0.154	0.003	0.028	98.713	0.000	0.000	0.000
2	2.183	0.420	0.411	6.024	80.334	10.508	0.105	0.011
3	2.553	0.419	0.574	6.258	79.322	10.660	0.111	0.098
4	2.724	0.419	0.586	6.289	79.129	10.633	0.119	0.098
5	2.805	0.419	0.585	6.297	79.043	10.630	0.119	0.098
6	2.839	0.419	0.585	6.299	79.011	10.626	0.119	0.098
7	2.855	0.419	0.585	6.299	78.998	10.624	0.119	0.098
8	2.861	0.419	0.585	6.299	78.992	10.624	0.119	0.098
9	2.864	0.419	0.585	6.299	78.989	10.623	0.119	0.098
10	2.865	0.419	0.585	6.299	78.988	10.623	0.119	0.098
Response of RTSI								
1	0.348	0.430	0.003	4.679	0.163	94.344	0.000	0.000
2	0.319	1.231	2.362	5.232	1.087	88.060	3.690	1.706
3	0.336	1.262	2.710	5.293	1.224	87.438	0.038	1.695
4	0.353	1.261	2.720	5.330	1.231	87.370	0.038	1.693
5	0.359	1.260	2.722	5.336	1.233	87.354	0.038	1.693
6	0.362	1.260	2.722	5.337	1.234	87.350	0.038	1.693
7	0.363	1.260	2.722	5.337	1.234	87.348	0.038	1.693
8	0.364	1.260	2.722	5.337	1.234	87.347	0.038	1.693
9	0.364	1.260	2.722	5.337	1.234	87.347	0.038	1.693
10	0.364	1.260	2.722	5.337	1.234	87.347	0.038	1.693
Response of FTSE JSE								
1	1.093	1.713	0.229	1.001	9.401	0.671	85.888	0.000
2	1.376	3.275	0.439	4.865	6.331	22.346	61.326	0.039
3	1.356	3.558	0.741	4.850	6.267	22.183	60.807	0.232
4	1.381	3.563	0.747	4.855	6.281	22.172	60.747	0.250
5	1.387	3.563	0.747	4.861	6.280	22.175	60.734	0.251
6	1.390	3.562	0.747	4.861	6.280	22.174	60.731	0.251
7	1.391	3.562	0.747	4.861	6.280	22.174	60.730	0.251
8	1.392	3.562	0.747	4.861	6.280	22.173	60.729	0.251
9	1.392	3.562	0.747	4.861	6.280	22.173	60.729	0.251
10	1.392	3.562	0.747	4.861	6.280	22.173	60.729	0.251

Table A11: Continued

Period	FFR shock	Brent Crude shock	Gold shock	SZSE CI shock	SENSEX shock	RTSI shock	FTSE JSE shock	BVSP Shock
Response of BVSP								
1	1.494	0.031	0.682	0.004	9.702	2.829	8.752	76.502
2	1.119	0.059	0.701	5.912	5.675	35.806	5.362	45.362
3	1.116	0.304	1.513	6.010	5.868	35.140	5.294	44.750
4	1.146	0.304	1.556	6.038	5.888	35.090	5.290	44.685
5	1.160	0.303	1.557	6.050	5.887	35.096	5.286	44.656
6	1.166	0.304	1.557	6.052	5.887	35.094	5.286	44.652
7	1.168	0.303	1.557	6.052	5.887	35.092	5.285	44.650
8	1.170	0.303	1.557	6.052	5.887	35.092	5.285	44.649
9	1.170	0.303	1.557	6.052	5.887	35.092	5.285	44.649
10	1.170	0.303	1.557	6.052	5.887	35.092	5.285	44.649

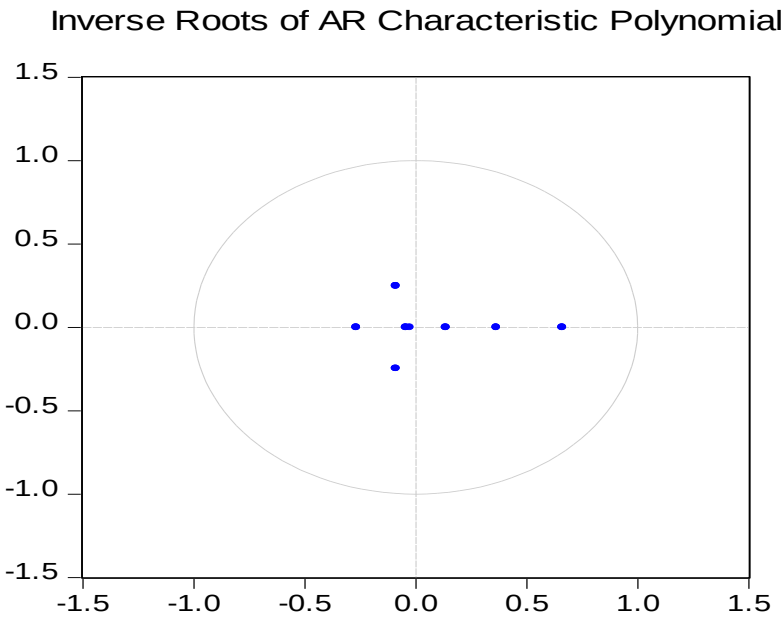
All variables, except FFR, are in log form and at first difference. The data series is noted in row 1. DFFR, DBRENT CRUDE and DGOLD stand for the Federal Fund Rate, Price of Brent crude per barrel and Price of gold per ounce respectively. DSZSE, DSENSEX, DRTSI, DFTSE JSE and DBVSP represent indices of the Shenzhen Stock Exchange, the Bombay Stock Exchange, the Moscow Stock Exchange, the Johannesburg Stock Exchange and the Sao Paulo Stock Exchange (B3) respectively. We report the response of all five indices only.

Table A12
Data Sources

Data	Sources	Descriptions
Federal Fund Rates	Federal Reserve Bank of St. Louis, USA	Announced monthly.
Brent Crude Price	Federal Reserve Bank of St. Louis, USA	Traded at electronic Intercontinental Exchange (ICE).
Gold Price	World Gold Council	We take price as USD per ounce.
Stock Indices	Yahoo Finance	

Figure A1

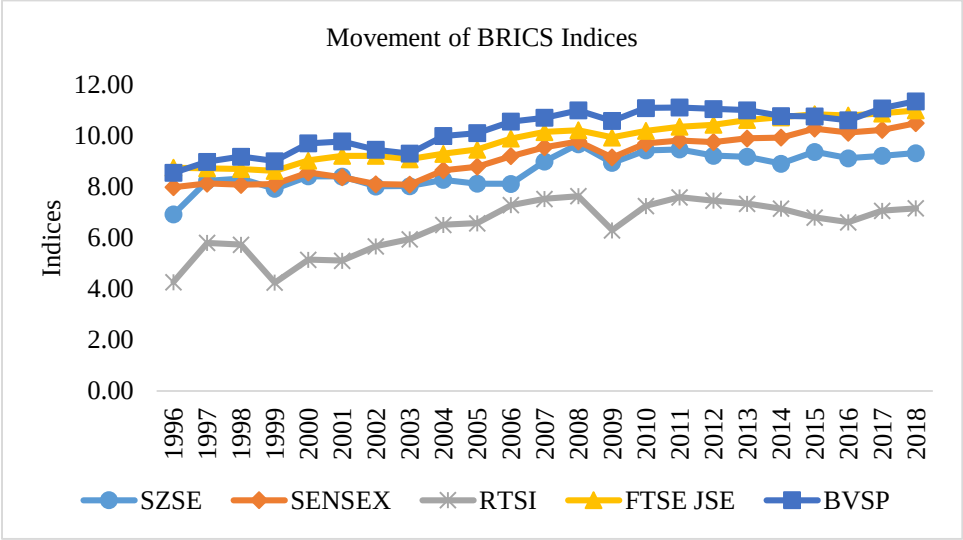
VAR Stability Test



No root lies outside the unit circle. VAR satisfies the stability condition.

Figure A2

Movement of BRICS Stock Indices

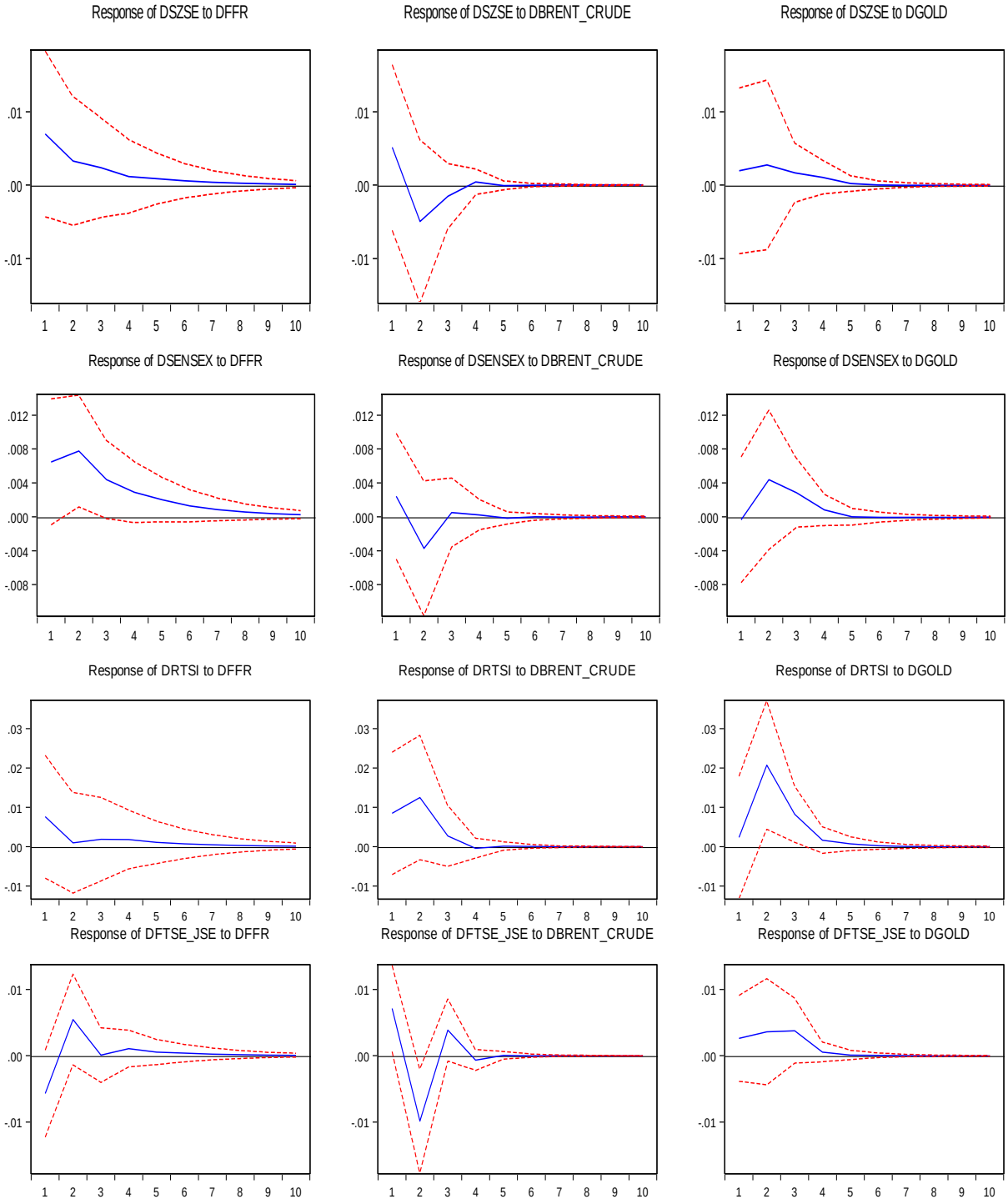


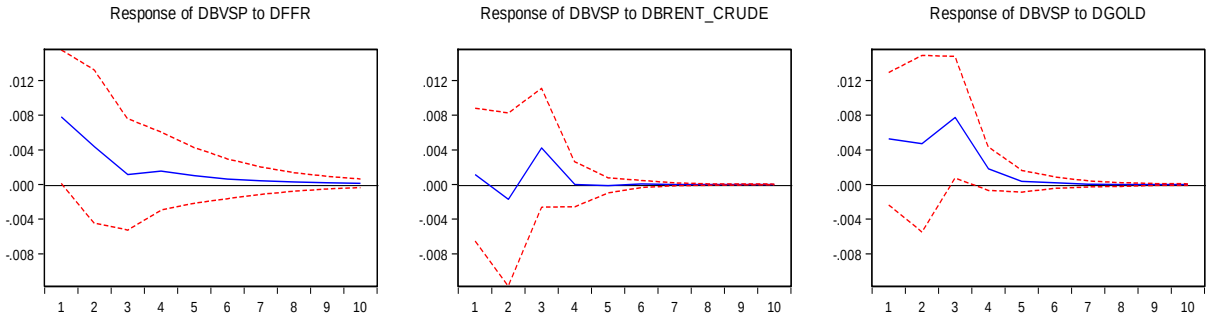
The figure is absed on level and log form from 1996 to 2018.

To give clarity of figure, the data taken for month of January every year.

Figure A3

Impulse Response Functions (Based on Cholesky Decomposition Method)





All variables, except FFR, are in log form and at first difference. DFFR, DBRENT CRUDE and DGOLD stand for the Federal Fund Rate, Price of Brent crude per barrel and Price of gold per ounce respectively. DSZSE, DSENSEX, DRTSI, DFTSE JSE and DBVSP represent indices of the Shenzhen Stock Exchange, the Bombay Stock Exchange, the Moscow Stock Exchange, the Johannesburg Stock Exchange and the Sao Paulo Stock Exchange (B3) respectively. We report response for ten months.

Research Office
Indian Institute of Management Kozhikode
IIMK Campus P. O.,
Kozhikode, Kerala, India,
PIN - 673 570
Phone: +91-495-2809237/ 238
Email: research@iimk.ac.in
Web: https://iimk.ac.in/faculty/publicationmenu.php