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Contagion between Developed and Emerging Markets

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Contagion between Developed and Emerging Markets

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Research Report submitted to Wits Business School, the University of the Witwatersrand. in partial fulfilment of the Master of Management in Finance and Investment.

Johannesburg, 2020

Declaration

I declare that this research report is my own unaided work. It is being submitted for the degree of Master of Management in Finance and Investment at Wits Business School, the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



Asheen Ashwin Bhagwandin

5th day of October in the year 2020

Abstract

This study examines the existence of contagion effects between the developed global economy and the BRICS economies (Brazil, Russia, India, China and South Africa) through the examination of linkages between global risk shocks and these markets. A structural vector autoregressive model with block exogeneity restrictions was estimated using macroeconomic and financial data for the BRICS markets and United States data (specifically the Volatility Index and the Federal Fund Rate) as proxies for global risk, all of a monthly frequency. Our primary findings are that contagion effects are present in exchange rates (besides China), sovereign credit default swap spreads and equity prices of our emerging domestic markets as a response of these variables to global risk shocks, although the magnitude of these effects varies by variable type and country. We do not observe significant responses to global risk shocks in government bond yields (besides Russian bonds) and exchange rates, and are thus unable to conclude, from our analysis, whether contagion effects affect these emerging market variables.

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List of Abbreviations

BRICS	Brazil, Russia, India, China, South Africa
CBOE	Chicago Board Options Exchange
CDS	Credit Default Swaps
DAG	Directed Acyclic Graph
DCC	Dynamic Conditional Correlation
GARCH Model	Generalised Autoregressive Conditional Heteroscedasticity Model
GDP	Gross Domestic Product
IMF	International Monetary Fund
JSE	Johannesburg Stock Exchange
NYSE	New York Stock Exchange
RTX	Russian Traded Index
SENSEX	Bombay Stock Exchange Sensitive Index
SSE	Shanghai Stock Exchange
SVAR Model	Structural Vector Autoregressive Model
US	United States
VAR Model	Vector Autoregressive Model
VIX	Volatility Index

1. Introduction

1.1. Background and Significance

In a global economy consisting of highly integrated financial systems, the spread of crises through financial contagion is a significant risk many players in the economic system face (Prabha, Barth & Kim, 2009). In recent years, this contagion effect has been witnessed on a global stage during events such as the Eurozone debt crisis, where extensive monetary integration assisted in the spread of sovereign debt default across several countries during the crisis (Baldwin & Giavazzi, 2015). Tabarrei (2014), through an analysis of the exposure of emerging economies to banks in Greece, Ireland, Italy, Portugal and Spain, indicates the significance of contagion effects through multinational banks. The study provides evidence, through an investigation of the common lender channel in international banking flows as a channel for contagion, that emerging economies with the highest exposure to the banking systems of developed nations are the most vulnerable to contagion effects due to widespread deleveraging in these developed banking systems.

Contagion effects are also evident during the subprime mortgage crisis in the US, the effects of which spilled over rapidly to various sectors of the US economy as well as other countries, leading to global banking sector failure, stock market crashes and economic recession (Prabha, Barth & Kim, 2009). Analyses by Frank and Hesse (2009) have identified indications of contagion effects by analysing variables proxying the market pressure in the US during the subprime mortgage crisis and have found correlation between these variables and emerging market variables.

Understanding the extent and effects of financial shocks spread through contagion from the global economy to that of each of the BRICS countries (Brazil, Russia, India, China and South Africa) would have the potential to identify the mechanism through which these crises are spread to these emerging market economies. Through this understanding, macroeconomic, monetary and financial risk management policies can be updated to mitigate these contagion effects better, thus shielding these emerging market economies from the resulting negative outcomes. Further, this increased understanding may assist investors in managing the risks to which asset prices are exposed due to these financial system shocks.

1.2. Problem Statement

The problem that this study aims to explain is highlighted in the following question. Do contagion effects exist between the global economy and emerging markets?

Much research has been conducted on the analysis of contagion, especially regarding the subprime mortgage crisis that originated in the US (Prabha, Barth & Kim, 2009). The salient implications of these studies on our study are described in the initial discussion of the methodology. From a preliminary review of the literature, the spread of financial crises due to contagion, from a global level to the BRICS countries, has not been as extensively studied as amongst larger or more developed economies. This creates great potential for further research and literary exploration in the context of this topic.

1.3. Research Objectives

This study aims to identify whether contagion effects exist through analysing the spread of financial shocks from the global economy, proxied by US factors, to the emerging economies of the BRICS countries.

The first objective of this study is to identify the optimal modelling technique that could be utilised to examine the spread of these financial shocks from the global economy to emerging markets. The second objective is to identify the macroeconomic variables, financial indicators and global risk factors that would best aid the analysis of financial risk shocks between the global economy and the BRICS markets. The final objective of this study is to identify the existence of contagion effects through the impact and significance of risk shocks on the identified variables.

Yildirim (2016) provides an analysis on the effects of global crises on asset markets in five fragile emerging markets through a structural vector autoregressive model with block exogeneity. This procedure, when altered to include macroeconomic factors and asset prices, as well as an examination of the effects of contagion on the BRICS markets, will form the basis of this paper.

1.4. Structure

The remainder of this investigation will consist of a literature review, which identifies and analyses a sample of relevant papers on the topic of contagion, of which the essential findings are extracted and summarised. This is followed by an overview of our methodology. In this section we identify the findings from the preliminary literature review to be integrated into our methodology. We then describe the rationale for the

choice of model before delving into the specifics of the analysed datasets, as well as the specifications and structure of the estimated model.

This is followed by a section detailing the empirical results, the concluding inferences of the study and, finally, recommendations for future study considerations and expansion.

2. Literature Review

In this literature review, we analyse a sample of relevant studies related to financial contagion and distil their salient points that may have implications on future studies of a similar nature. These implications are further investigated in the context of this study in the methodology section.

2.1. Financial Contagion and Network Analysis

The concept of financial networks where contagion is spread through financial linkages has been explored widely in literature. Leitner (2005) discussed this concept in the context of private sector banks with surplus liquidity being able to bail out those that are less liquid in the face of contagion risk, thus creating an informal form of mutual insurance through optimal linkages. Leitner (2005) characterises the optimal network design through exploring the trade-off of spreading risk amongst the network and the potential for a network-wide collapse, taking into account the assumption of a network coordination mechanism.

Allen and Babus (2008) have expanded their consideration from an interbank view, to one which includes investment banks and microfinance institutions, purporting that network analysis is crucial in the understanding of financial phenomena, especially in the context of these intermediary institutions. The considerations of financial institutions as interlinked nodes is briefly introduced as a means of meaningfully describing and analysing the theory of financial networks (Allen & Babus, 2008).

The structure of financial networks is examined more robustly by Glasserman and Young (2015) through the Eisenberg-Noe framework of node analysis, combining each node in

a network's net worth, external leverage and financial connectivity into a contagion index that indicates each node's influence on potential failure through contagion effects. This model is useful in identifying a financial institution's potential impact on the network in which it is integrated.

The analysis indicated that network structure may be less relevant to contagion effects through loss spillover in an integrated network. Rather, it may be more relevant to the amplification effects where a chain of nodes causes a cycle of losses through the amplification of the initial shock of a payment obligation not being made (Glasserman & Young, 2015).

Summer (2013) provides an overview of recent studies regarding interbank contagion, as well as a discussion of theoretical concepts regarding network models of default cascades, and their major findings and limitations. Summer (2013) examines the question of whether a network of financial exposure that is extremely interconnected may mitigate aggregate risk through diversification, thus making the system more resistant to shocks, or whether these networks are prone to the contagion of shocks, considering information asymmetries regarding the pattern of exposure.

Relying predominantly on simulation studies conducted in previous research, Summer (2013) concludes that contagion risk is small when analysed in the context of the domino effect of balance sheet linkages. This study suggests that weight needs to be shifted from the traditional focus on the domino effect of default cascades to the amplifiers of the effects of contagion, and should be combined with macroeconomic market theory, individual behaviour and pricing. This will provide a more holistic view on contagion.

2.2. Bankruptcy Cascades, Diversification and Integration

Bankruptcy cascades as a result of systemic risk being shared in an interbank market have been explored by Tedeschi et al. (2012) in a study that considers how the diversity of participants in financial networks and the level of their integration affect the trade-off between their mutual insurance and potential contagion effects. The study concludes that higher levels of interbank integration result in greater fragility of the system and larger bankruptcy cascades due to greater systemic risk.

A study by Stiglitz (2010) further consolidates these findings from a macroeconomic perspective, purporting that whilst there are benefits to systemic integration and correlated business strategies, this integration reduces the effects of diversification and increasing contagion risks. Stiglitz further comments that unintentional correlated behaviour due to macroeconomic shocks could also induce such exposure, resulting in bankruptcy cascades due to network fragility (Stiglitz, 2010).

Roukney et al. (2013) further explore cascading dynamics through a comprehensive analysis that considers network topology, individual node robustness, contagion strength and random and targeted initial shocks as the main drivers of default cascades. The study concludes that network topology does not solely determine network stability, and the optimal network architecture depends on a balance between the dilution effects of load redistribution of systemic risk and failure in the network, as well as the amplification effects of contagion.

Elliott et al. (2014) purport that increased integration in financial systems leads to increased exposure of firms to one another, and, thus, to increases in the probability and extent of contagion. This study examines cascades in financial networks through a model

of cross-investments amongst firms that allows discontinuities in values. Elliot et al. (2014) arrive at the conclusion that it is essential to differentiate between diversification and integration, as each has discrete effects on contagion, and contains unique trade-offs in how they impact contagion. The study alludes to the fact that an endogenous study of a network of cross-holdings and of asset-holdings would be a beneficial next step in the analysis of contagion.

2.3. Attention Allocation Theory

Traditional transmission mechanisms such as cross-market hedging in stock markets, herding due to globalisation, information asymmetries and borrowing constraints, comovement through similar trading strategies etc. are important in understanding contagion. However, Mondria and Quintana-Domeque (2013) propose attention allocation as a contemporary mechanism that may assist in furthering our understanding of contagion due to its extensive theoretical backing in psychology.

Attention allocation purports that human cognition contains limited capacity for information processing, as well as the execution of multiple simultaneous tasks. This is in direct violation of the assumption of financial asset pricing modelling, which posits that market investors process all available, relevant information in their decision making (Mondria & Quintana-Domeque, 2006).

Corwin and Coughenour (2008) analyse attention allocation theory in the context of market making on the New York Stock Exchange (NYSE). The NYSE proved a beneficial platform to study, as the securities amongst which trading specialists are required to divide their attention are easily identifiable, and the trading activities of the

securities in the individual specialists' portfolios, as well as the transaction costs of trading, can be utilised as a measurement factor for attention allocation.

The analysis provides evidence that limited attention influences the liquidity provided by these specialists in financial markets due to the divide of attention across multiple securities, thus resulting in potential inefficiency costs associated with the structure of traditional markets such as the NYSE. These inefficiencies, in aggregate, may contribute to contagion effects (Corwin & Coughenour, 2008).

Mondria and Quintana-Domeque (2013) provide a model of rational expectations of asset prices with information processing constraints. The model aims to explain the transmission of contagion as a change in the attention allocation of investors in the short term. The study finds that if investors are surprised by an unanticipated financial crisis shock, then contagion occurs through attention reallocation. If, however, a shock is anticipated, more capacity to process information is acquired and the effect of contagion through asset reallocation is minimised. This model thus justifies the existence of international credit ratings agencies (Mondria & Quintana-Domeque, 2013).

2.4. Equity Market Contagion

Bekaert et al. (2014) examine how and why the effects of the US subprime mortgage crisis spread with such volatility across such a wide array of countries and economic sectors. This study utilises a three-factor model, distinguishing between a US factor, a global factor and a domestic factor, to benchmark equity market comovements of 415 equity portfolios across 55 countries.

The study, through its interdependence model, finds evidence of contagion, as the model explains 75% of total predictable return. The study also finds that contagion did not spread

indiscriminately. Rather, countries with poor economic fundamentals, relatively low ratings of sovereign credit and high current account and fiscal deficits were more prone to contagion and were more affected by the financial crisis (Bekaert et al., 2014).

In a similar study, Dungey and Gajurel (2014) utilise a latent factor approach that tests for contagion by identifying the US as the crisis originating country, and the four largest advanced economies and emerging countries by GDP from 2004 to 2010. The study found strong evidence of contagion effects from US equity markets to equity markets in both advanced and emerging markets.

Prior to the US subprime mortgage crisis, contagion across equity markets was studied by Chan-Lau, Mathieson and Yao (2004), using dependence measures based on the joint behaviour of equity market returns. This study indicated that whilst contagion effects exist in equity markets, contagion patterns significantly differ across varying regions. It also finds that contagion effects are of greater significance for negative returns than positive returns, and that the use of correlation as a proxy for contagion may yield misleading results, as external dependence measures of contagion and simple correlation measures are not significantly correlated.

2.5. Measurement of Contagion and Econometric Issues

Forbes and Rigobon (2001) make a point of dispelling ambiguity regarding the concept of contagion by defining it as a significant increase in cross-market linkages after a shock to a country or group of countries. This is done to enable more precise measurement of the phenomenon by allowing for the testing of changes in cross-market linkages after financial shocks. Forbes and Rigobon (2001) believe this definition to be beneficial in evaluating the effectiveness of international diversification, the justification of

multilateral intervention, as well as differentiation of the transmission mechanisms of financial shocks.

Viale, Bessler and Kolari (2014) similarly found the development of a robust test of contagion effects problematic due to lack of agreement on a precise definition of the concept. This study goes on to define contagion as a spillover that cannot be explained in terms of economic fundamentals, and a financial contagion event as a structural shift in the transmission mechanism linking a financial market network after a local negative shock.

Viale, Bessler and Kolari (2014) continue to build on the robust methodologies of previous studies by furthering the development and application of directed acyclic graphs (DAGs). These allow for the economic interpretation of the multi-factor model of asset returns characterised by a reduced form vector autoregressive (VAR) model, providing a contemporaneous causal structure of the innovations when minimal theoretical knowledge exists.

Pesaran and Pick (2004) provide an econometric background to contagion and investigate the conditions under which contagion can be differentiated from interdependence. The paper also examines herding behaviour in financial markets. In their examination of econometric models, Pesaran and Pick (2004) conclude that, in the presence of interdependence, country-specific fundamentals are essential for the estimation of contagion effects, which highlights the pitfalls of existing studies that focus on high frequency data and ignore country specific fundamentals.

To achieve a model that successfully identifies contagion, Pesaran and Pick (2004) purport that it is essential that the data are split into “crisis” and “non-crisis” periods, as well as divided according to the source country and affected countries.

2.6. Contagion to Emerging Economies

Through a structural vector autoregressive (SVAR) model, Yildirim (2016) examines the effects of financial conditions on the asset markets in five fragile emerging economies. This study examines the spread of contagion to these economies through capital flows and asset prices by two permeating factors, namely global risk and US monetary policy.

Yildirim (2016) finds strong supporting evidence that global financial risk shocks have significant effects on the asset prices of the examined fragile economies, with effects varying across asset classes according to foreign holdings in these economies. This study concludes that the strength of macroeconomic fundamentals plays a strong role in mitigating the vulnerability to contagion, especially in the face of the disruptive effects of the tightening of global financial conditions.

The financial interlinkages between advanced economies and emerging markets were examined in a study by Frank and Hesse (2009) which analysed the comovements of several financial variables. The study utilises a multivariate generalised autoregressive conditional heteroscedasticity (GARCH) model to effectively analyse the extent of comovements of markets by inferring the correlations of changes in the examined variables which is essential in determining whether a recent financial crisis has become systemic. The study concludes that during the period of the US subprime mortgage crisis, relevant variables proxying pressures in the US market became correlated with emerging market variables, indicating evidence of contagion effects (Frank & Hesse, 2009).

Bonga-Bonga (2018), in a similar study, evaluates the extent of contagion between South Africa and each of the remaining BRICS countries (namely Brazil, Russia, India and China) during a period of financial crisis in each of the countries and attempts to assess conditional correlation between South Africa and each of the other BRICS countries during these periods. The study utilises a multivariate vector autoregressive dynamic conditional correlation GARCH (VAR-DCC GARCH) model to assess the magnitude of financial shock transmission in an effort to determine contagion effects.

The findings of this study conclude that interdependence exists between Brazil and South Africa; however, South Africa is more affected by crises originating in Russia, India and China than these countries are affected by crises originating in South Africa (Bonga-Bonga, 2018).

3. Methodological Considerations

This section follows the approach of assimilating the salient findings from the literature review into our analysis, and subsequently describes the rationale for why the chosen model is the best fit for the purpose of this study. This is followed by sections detailing the specifics of the datasets utilised, the treatment of the data and the specifications of the estimated model.

3.1. Initial Inferences from the Preliminary Literature Review

This study utilises the definition purported by Forbes and Rigobon (2001) of contagion being characterised by the significant increase in cross-market linkages after a shock to a country or group of countries. For the purposes of this study, the shocks are applied to the global risk proxy, and the results of these are analysed in the studied domestic market variables, in an attempt to analyse the transition mechanisms of these shocks, as suggested by Forbes and Rigobon (2001).

As Summer (2013) suggests, weight in our model is shifted from default cascades to macroeconomic variables, as well as financial indicators such as asset prices that capture the effects of individual behaviour (in the form of sovereign credit default swaps (CDS), government bond yields and equity prices). The emerging markets of the BRICS economies are the domestic markets chosen for analysis due to the suggestion of Bekaert et al. (2014) that countries with relatively poor economic fundamentals, low sovereign credit ratings and high current account and fiscal deficits are more prone to contagion. The BRICS countries, being classified as emerging markets, are prone to some of these effects.

In line with Pesaran and Pick's (2004) econometric guidelines, the data should be split according to source and affected country; this approach is adopted here. In the construction of the model, periods of financial crisis and non-crisis are also included definitively to ensure a robust model estimation. Yildirim (2016) further makes a strong case for the use of a structural vector autoregressive model with block exogeneity in the examination of contagion due to shocks from a global platform to emerging economies. This study is the primary focus and theoretical backbone of our study.

3.2. Model Rationale

Our proposed methodology follows that of Yildirim (2016), utilising a structural vector autoregressive (SVAR) model with block exogeneity in an effort to investigate the effect of global financial shocks on the BRICS economies. Yildirim (2016) comments that using a SVAR model with block exogeneity to analyse the impact of these shocks on emerging economies has become the empirical standard, as it allows dynamic systems to be dissected into two discrete blocks, namely the domestic and external markets. The assumption that the domestic market is small, with negligible influence, can be incorporated into this model by excluding the lag coefficient of the domestic variables from the block equations of the external markets. This assumption of block exogeneity allows us to mitigate the spurious contagion effects and renders a model that describes the impact of external shocks on domestic markets more accurately and robustly. Theoretically, a SVAR model that caters for block exogeneity also assists in efficiency of the estimated regression by reducing the number of parameters that need to be estimated.

Several variables are utilised in our model, two of which are macroeconomic variables that are open to global influence due to the open nature of the economies examined. These are the interest rate and exchange rate of the respective markets analysed. These factors are supplemented with financial indicators, namely sovereign CDS spreads, government bond yields and equity prices which provide indicators of financial market performance within each country.

The domestic markets analysed in this study are those of the BRICS countries, as these are emerging market economies with easily accessible data yielded by their relatively mature financial systems. The external market that proxies the influence of global financial markets in our analysis is that of the US, due to its monetary policy influence on global investor risk aversion, which influences capital inflows to emerging markets. The US has further played a primary role in driving the subprime mortgage financial crisis. As such, in our analysis, global risk is proxied by the Volatility Index and the US monetary policy is proxied by the US Federal Fund Rate (Yildirim, 2016).

The following sections address the datasets utilised as well as the SVAR model specifications.

4. Data Sources and Transformations

This section will discuss the data utilised in the estimation of the SVAR model. The datasets contain data of monthly frequency, from January 2005 to December 2018 of all variables, split by source (i.e. the US) and affected countries (i.e. the emerging BRICS markets), as suggested by Pesaran and Pick (2004). The sample period of 2005 to 2018 contains data obtained during three key financial crises, namely, the subprime mortgage crisis which had effects spanning from 2007 to 2010, the European sovereign debt crisis, spanning from 2009 to 2012, and the taper tantrum which affected the US bond market in 2013. Due to the sample period further containing periods of non-crisis due to the span of observed data, we satisfy the suggestion of Pesaran and Pick (2004) of including both crisis and non-crisis data in the model to assist accurate and robust estimation.

As suggested by Summer (2013), the data will contain both macroeconomic variables as well as financial variables. These are described as follows.

4.1. Domestic Variables: Macroeconomic Variables

4.1.1. Exchange Rates

Exchange rate fluctuations can be indicative of changes in macroeconomic variables in economies open to global influences, especially in small domestic markets (Ozcelebi, 2017). The exchange rate data provided are stated in terms of local currency per US Dollar.

4.1.2. Interest Rates

There are many macroeconomic variables that affect interest rates. Interest rates are thus open to the various global influences that impact these variables (Kudlacek, 2008). The specific interest rates utilised per domestic economy are as follows. The Selic rate is used for Brazil, interbank rates are used for Russia and India, the Chinese Central Bank base interest rate is used for China and the Prime Lending rate is used for South Africa. All interest rates are stated in terms of percentage per annum.

4.1.3. Domestic Variables: Financial Variables

4.1.3.1. CDS Spreads

Five-year sovereign CDS spreads are utilised in our analysis, as these instruments allow for the transfer and management of sovereign credit risk in hedging, speculating and trading. They further reflect the general conditions of the asset markets of the country in question (IMF, 2013).

4.1.3.2. Government Bond Yields

Five-year government bond yields are utilised to gauge adequately the effects of global financial shocks on a country's government bond market, which are sensitive to macroeconomic fluctuations (Nishat & Ullah, 2017).

4.1.3.3. Equity Prices

The primary equity index is utilised for each country as an indicator of financial performance of the equity market in each respective country. The Bovespa Index is used for Brazil, the RTS Index is used for Russia, the SENSEX Index is used for India, the SSE Composite Index is used for China and the JSE All Share Index is used for South Africa.

4.1.4. Foreign Variables: Global Proxies

As discussed, we utilise US-based variables as the basis measure for global financial markets. This is due to strong correlations between international risk aversion and US monetary conditions as well as the evidence suggesting that US price asset price and market movements drive movements in emerging markets (Yildirim, 2016). The Volatility Index, provided by the Chicago Board Options Exchange, provides a forward-looking view of investor sentiment to market risk and volatility (CBOE, 2020). It is used as the primary proxy for global market risk. The US Federal Fund Rate, similarly, proxies monetary policy in the US. We utilise the US Baa corporate spread as a secondary proxy of global risk as suggested by Yildirim (2016).

4.1.5. Data Transformations

These data will allow us to identify accurately the contagion effects of external shocks to the BRICS economies due to the information-rich nature of the varied spread of data over the time period analysed. To normalise the data in an effort to increase the reliability of the estimated model, we apply logarithm transformations to all exchange rates, CDS spreads and equity prices. Interest rates and bond yields are utilised in level form due to being measured in percentages.

4.1.6. Data Limitations

In the collection and compilation of the data, two limitations were encountered. Firstly, the industrial production index of each country was intended to be used as a measure of domestic economic output for each emerging economy. Upon investigation, it was apparent that the industrial production index data for India, China and South Africa were

not available for the majority of the sample period and would thus not enhance the validity or reliability of the estimated model.

Secondly, the CDS spread data for India were not available prior to October 2013. While this is a large gap, the data for the other four domestic markets were readily available. We thus utilised the unconditional mean imputation of the CDS spread data for the period, as using zero values for the missing data negatively impacts the estimation of the model in terms of logarithmic transformations (Pratama, Permanasari, Ardiyanto & Indrayani, 2016).

For details of the data sources, please refer to Appendix A.

5. Model Estimation

The methodology utilised in the estimation of our SVAR and the generation of the necessary impulse response functions are discussed in this section.

5.1. Reduced Form Equation of Contagion Effects

We examine the following model:

$$\sum_{s=0}^{p} \begin{bmatrix} A_{1,1}(s) & A_{1,2}(s) \\ A_{2,1}(s) & A_{2,2}(s) \end{bmatrix} \begin{bmatrix} x_{t-s}^{d} \\ x_{t-s}^{e} \end{bmatrix} = \begin{bmatrix} \varepsilon_t^{d} \\ \varepsilon_t^{e} \end{bmatrix}$$

In this model $A_{i,j}$ represents the coefficient matrix, $y_t = [x_t^d, x_t^e]$ represents a vector of variables, and $\varepsilon_t = [\varepsilon_t^d, \varepsilon_t^e]$ is a vector of structural disturbances. ε_t^d is a vector of structural shocks of domestic origin, whilst ε_t^e is a vector of structural shocks of external origin. x_t^d is a vector of variables of the open, emerging economy (representing each of the BRICS countries in this study). x_t^e represents a vector of variables of the global market (proxied by US variables), external to the emerging economy domestic markets.

5.1.1. Model Specifications

A two-step process will be utilised to estimate this model. First, the reduced form VAR, illustrated above, is estimated using regressions with first differences of all variables and one lag. First differences of variables are used so as to control for non-stationarity in the time series data. The VAR is estimated using a single lag, as we allow the autoregressive effects of the variables on one another to exist in the model for only a single period. This is similar to the VAR estimation of Yildirim (2016).

The block exogeneity restrictions, the specifics of which are discussed below, are applied to the model to estimate the SVAR, and impulse response functions are subsequently generated, bootstrapped by probability bands, using a Monte Carlo algorithm with 250 repetitions.

5.1.2. Block Exogeneity Restrictions

The model estimation is dependent on the following exogeneity assumptions. Firstly, we assume that the financial markets of the BRICS economies, being emerging markets, are not significant enough to exert a substantial effect on the global financial conditions. As such, we are required to apply a restriction that allows the global variables to affect domestic variables, both in a lagged and contemporaneous manner, but that disallows domestic variables from affecting global ones.

Secondly, we assume that, within the global, external block, the US Federal Funds rate exerts an effect on the Volatility Index, our measure of global risk, but not vice versa. We thus need to build this restriction into our A(0) matrix in the estimation in our VAR.

Finally, we make the assumption that domestic variables exert contemporaneous effects across the variable classes and markets. We thus attempt to limit restrictions on structural parameters as far as possible amongst these variables.

5.1.3. Identification Problem

Due to the nature of SVAR estimation which utilises simultaneous equations, we are faced with a problem of a limitation of the number of coefficients able to be estimated in the A(0) matrix without restrictions (Hall, 1988). In an effort to estimate a ‘just identified’

model, we need to impose a $\frac{n(n-1)}{2}$ restriction on the parameters in the A(0) matrix, which can prove extremely challenging.

Due to the limitations on Bayesian VAR estimation and parameter restrictions in EViews 11 preventing an estimation of a 'just identified' SVAR, we utilise a recursive identifications scheme, namely the Cholesky Decomposition. This recursive scheme utilises a unit triangle, imposes zero restrictions in the upper triangle of the A(0) matrix, and allows for contemporaneous effects through non-restrictions in the lower triangle. This scheme allows for the $\frac{n(n-1)}{2}$ restriction to be satisfied and, thus, for the model to be 'just identified' (Hall, 1988).

In an effort to apply the aforementioned exogeneity assumptions appropriately and to ensure a reliably estimated model, it is important that we consider the ordering of the variables in the Cholesky scheme carefully. We thus position the US Federal Fund Rate first in our scheme, and the Volatility Index (VIX) second, due to our first and second block exogeneity assumption discussed previously. We then attempt to fit our variables to the remainder of the recursive scheme matrix as closely as possible, ordering our domestic market variables from those that would experience the least contemporaneous effects from other variables to those that would experience the most, namely exchange rates, interest rates, sovereign CDS spreads, government bond yields and equity prices. We, however, reverse the order of the variables in the scheme as part of a robustness analysis to assess whether the order of domestic variables has a significant effect on the scheme.

In terms of the ordering of the BRICS countries (within the variable order), we utilise trade as a percentage of GDP (in 2018) as a measure of economic openness, to ascertain

which economies are likely to have a greater contemporaneous effect on the other domestic economies.

We make the assumption that the greater the degree of openness of a country, the greater its effects on the other BRICS economies in the model, and thus order countries from most to least open per variable in the Cholesky Decomposition scheme. These data were obtained from World Development Indicators (2020), and the summary of openness order is illustrated in Table 1, below.

Country Name	Trade as Percentage of GDP (2018)	Openness Order
South Africa	59.470%	1
Russia	51.510%	2
India	43.378%	3
China	38.246%	4
Brazil	29.082%	5

Table 1: Country Openness indicated by Trade as a Percentage of GDP

The specification of our A(0) matrix, taking into account the aforementioned restrictions and considerations in the recursive Cholesky Decomposition scheme is summarised in the matrix in Figure 1. Note that in an effort to maintain compactness and ease of understanding, the ordering of countries is not described in the summary matrix.

$$A(0) = \begin{array}{c} \\ \text{FFR} \\ \text{VIX} \\ \text{Exch} \\ \text{Int} \\ \text{CDS} \\ \text{Bond} \\ \text{Equit} \end{array} \begin{array}{c} \begin{array}{ccccccc} \text{FFR} & \text{VIX} & \text{Exch} & \text{Equit} & \text{CDS} & \text{Bond} & \text{Equit} \end{array} \\ \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & 0 \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 \end{bmatrix} \end{array}$$

Key	
FFR	= US Federal Fund Rate
VIX	= Volatility Index
Exch	= Exchange Rate
Int	= Interest Rate
CDS	= Sovereign CDS Spread
Bond	= Government Bond Yield
Equit	= Equity Price

Figure 1: A(0) Matrix Specifications

The recursive scheme in the A(0) matrix in Figure 1, applied to the SVAR results in a 'just identified' model estimate. The impulse responses, bootstrapped by 95% confidence bands, can thus be utilised reliably to estimate the effects of shocks in the global risk measure (i.e. the VIX) to the various domestic variables. These empirical results are analysed in detail in the following section.

6. Empirical Results

In this section, we explore the empirical results gleaned from our SVAR model. We begin by analysing the impulse response functions. These allow us to examine the dynamic effects of a shock to our global risk measure, the Volatility Index, on the macroeconomic and financial variables in the model. These variables are examined per country in an effort to determine the existence and scale of contagion effects on each variable in each of the BRICS economies.

As suggested by Hall (1988), our impulse responses are bootstrapped by 95% confidence bands. These are simulated using the Monte Carlo method with 250 replications in the construction of the impulse response functions in a similar fashion to Horvath (2008). These confidence bands will provide an indication of statistical significance of our impulse response functions.

Secondly, we consider variations across the BRICS economies in the immediate response of the macroeconomic and financial variables to a shock in the global financial risk factor. We examine the varied differences in magnitude of these variables to the Volatility Index shock to determine the extent of these variations.

The analysis of these results will provide an indication of whether contagion effects do exist between the developed global financial markets and the BRICS economies.

6.1. Brazilian Impulse Response Functions

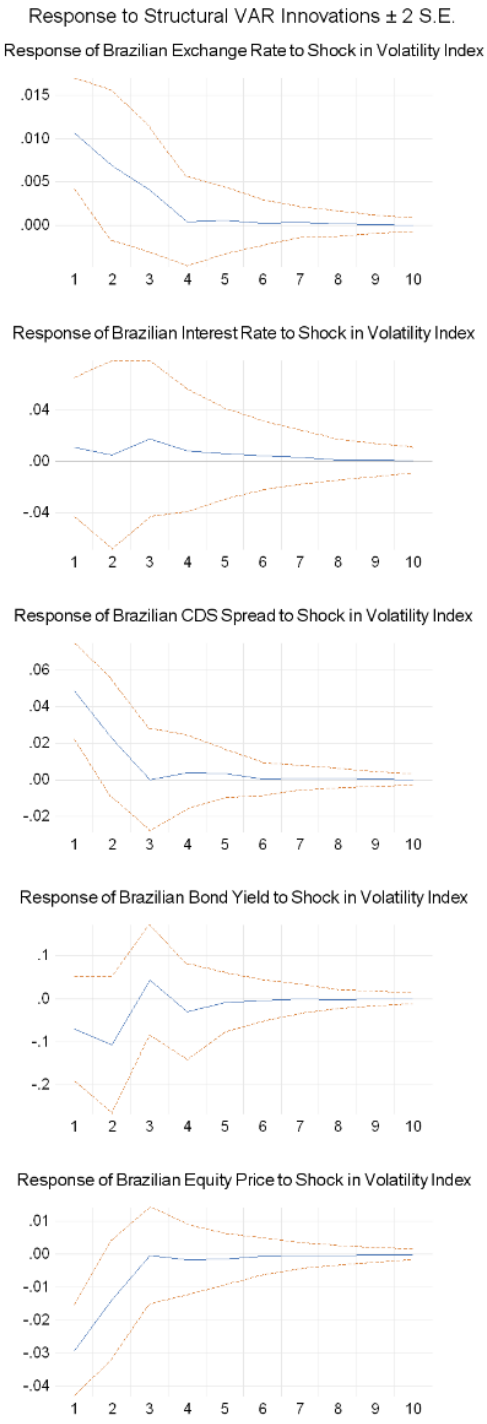


Figure 2: Brazilian Impulse Response Functions

We notice that the response of the Brazilian exchange rate to a one standard deviation shock in the global risk factor is initially positive and significant. It, however, begins to decrease and die out and is not significant from the second period onwards.

The response of the Brazilian interest rate as a result of the global risk shock is not statistically significant throughout. This non-significant response appears to be initially positive, marginally decreases to period two, increases to period three and then dies out to zero over the remaining periods.

The response of the Brazilian CDS spread appears to be initially positive and significant, indicating a deterioration in domestic market conditions. It rapidly declines to period three, and becomes non-significant at period two before eventually dying out.

The response of the Brazilian government bond yield to the global risk shock is non-significant throughout. The response is initially negative and declining, increases from period two to

a positive response to period three, decreases to a negative response to period four and gradually dies out to zero. Speculatively, this negative response could be indicative of individuals wanting to invest in what they consider to be safer investments, causing yields to decline and bond prices to increase. The responses, however, are not statistically significant and, thus, cannot be considered.

The response of Brazilian equity prices is initially negative and significant; it increases sharply up to period three, although it becomes non-significant at period two and subsequently gradually dies out.

We thus observe a decline in the Brazilian market and economy, to a deterioration in global risk sentiment (i.e. a positive shock to the Volatility Index). We notice a significant, negative response by equity prices. The response of the exchange rate and the CDS spread is initially significant and positive, indicating an immediate deterioration in the domestic economy. The responses of interest rates and bond yields are, however, not statistically significant and thus cannot support our results.

6.2. Russian Impulse Response Functions



Figure 3: Russian Impulse Response Functions

We observe an initial, significant depreciation in the Russian exchange rate as a result of a global risk shock. This depreciation increases up to period two after which the response becomes non-significant and declines sharply to period three. The exchange rate response marginally increases to period four and gradually dies out.

The Russian interest rate response is not statistically significant throughout and thus cannot be utilised to support our analysis. It, however, appears to decrease, below zero, sharply from a positive response, and sharply increases to a positive response, gradually dying out.

The response of the Russian CDS spread increases steeply over the first two periods from an initial significant, positive response, indicating a domestic economic deterioration. It then steeply declines to zero, becoming non-significant around period three. It increases from period four to five and gradually dies out.

The response of Russian government bonds is initially positive and significant, but declines at a rapid pace, becoming non-significant and negative between periods one and two. The non-significant response then fluctuates, dying out over time. This indicates an initial decrease in bond price, which is indicative of declining financial conditions in Russia.

The equity price response to a global risk shock is initially negative and significant, steeply increases to zero to period three, and becomes non-significant at period two. This non-significant response marginally decreases and gradually dies out.

Overall, we observe a decline in Russian financial conditions, in response to a negative global risk sentiment. We notice an initial significant negative response in the Russian equity market, an initial significant depreciation of the Russian Ruble, as well as a significant positive response in the CDS spread and bond yield, indicating economic deterioration in Russia. The responses of interest rates are, however, not statistically significant and thus cannot support our results.

6.3. Indian Impulse Response Functions

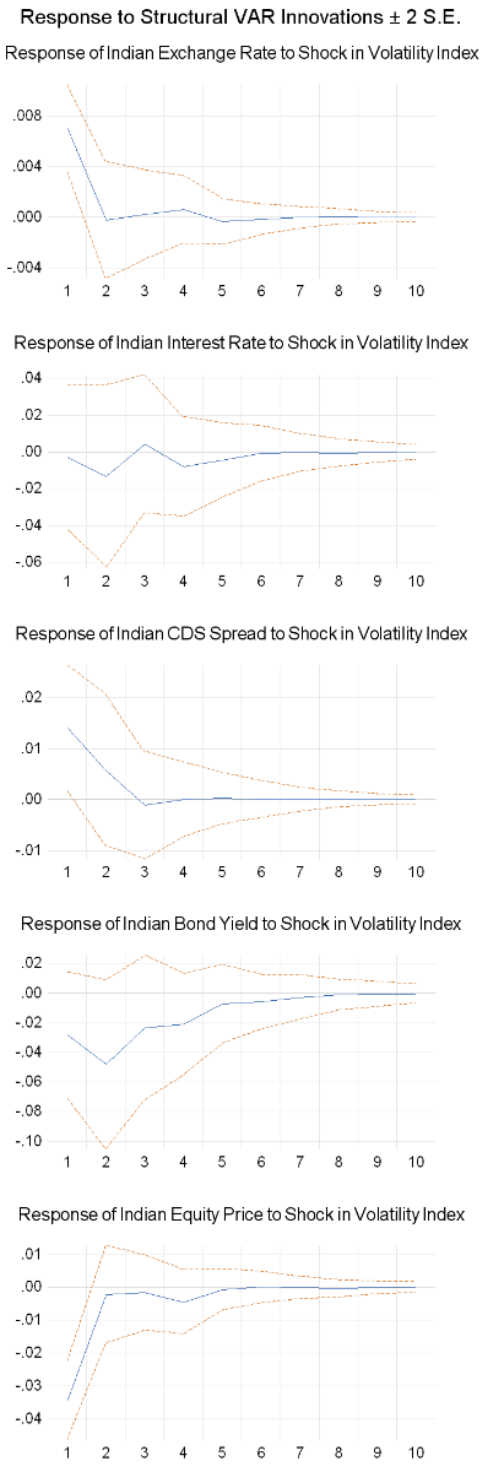


Figure 4: Indian Impulse Response Functions

The Indian exchange rate response is initially significant, showing depreciation in the Rupee. It sharply appreciates to a nil response in period two, becoming non-significant between periods two and three. The non-significant response fluctuates and dies out.

The Indian interest rate response is not significant throughout and thus cannot support our results. This non-significant response fluctuates around zero before dying out.

The Indian CDS market response is initially significant and positive, indicating domestic economic deterioration. The response steeply decreases and becomes negative at period three, becoming non-significant between periods one and two. The non-significant response gradually dies out.

The Indian bond market exhibits an initial negative response to a global risk shock, deteriorating up to period two and subsequently gradually increasing, eventually dying out. This could be similar to the response of Brazil, where investors are seeking out a perceived

safe haven for their investments. The responses, however, are not statistically significant and thus cannot be considered in our analysis.

The equity market exhibits an initial significant negative response to a global risk shock. This increases steeply to almost zero at period two, with a negative fluctuation around period four, eventually dying out. The response becomes non-significant between periods one and two.

The analysis above indicates a negative economic response to a global risk shock, with the equity market indicating a significant negative response. The Rupee depreciation and increase in CDS spreads further indicates economic decline. The responses of interest rates and bond yields are, however, not statistically significant and thus cannot support our results.

6.4. Chinese Impulse Response Functions

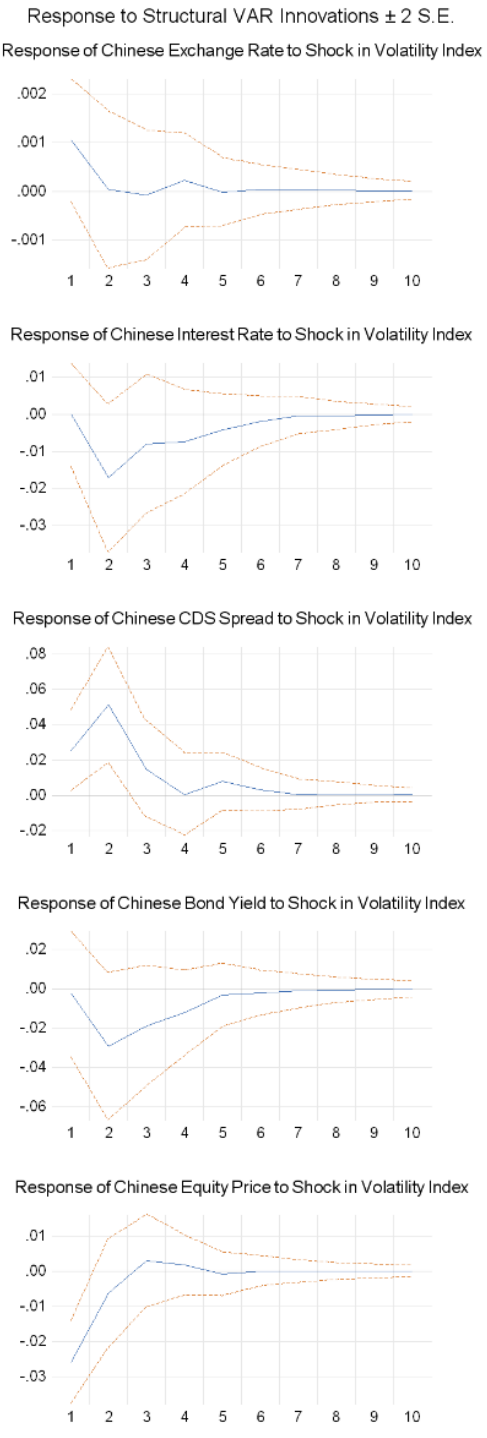


Figure 5: Chinese Impulse Response Functions

We notice a response of the Chinese Yuan exchange rate to a global risk shock that is not statistically significant throughout the response period, and thus cannot support our analysis. The currency initially depreciates and, subsequently, marginally appreciates to zero up to period two and then fluctuates around zero before dying out. The non-significant nature of this response function could be due to the fact that the Chinese Yuan is pegged to the US dollar by the Chinese Central Bank.

The response of the Chinese interest rate to a global risk shock is initially negative and steeply decreases up to period two. We subsequently observe an increase in the interest rate response, which dies out to zero. These responses are, however, also not statistically significant throughout and thus cannot support our results.

We notice an initial positive response and steep increase in the response of the Chinese CDS spread to a global risk shock up to

period two, indicating unfavourable domestic conditions. The response becomes non-significant between periods two and three, decreasing to zero at period four. This non-significant response increases marginally at period five and then dies out.

The response of Chinese government bond yields is initially almost nil and decreases steeply up to period two, again indicating a possible investment safe haven. The bond yield response begins to increase gradually from period three, eventually dying out. This response function is also not statistically significant throughout and thus cannot support our analysis.

The Chinese equity market response to a global risk shock is initially negative and significant. This gradually increases, becoming positive at period three, after which it gradually dies out. The response becomes non-significant after period two.

The overall response of the Chinese markets indicates a negative response to the global risk shock through significant, unfavourable CDS market and equity market responses. The response of the bond yield, interest rate and exchange rate are, however, not statistically significant and thus cannot support our findings.

6.5. South African Impulse Response Function

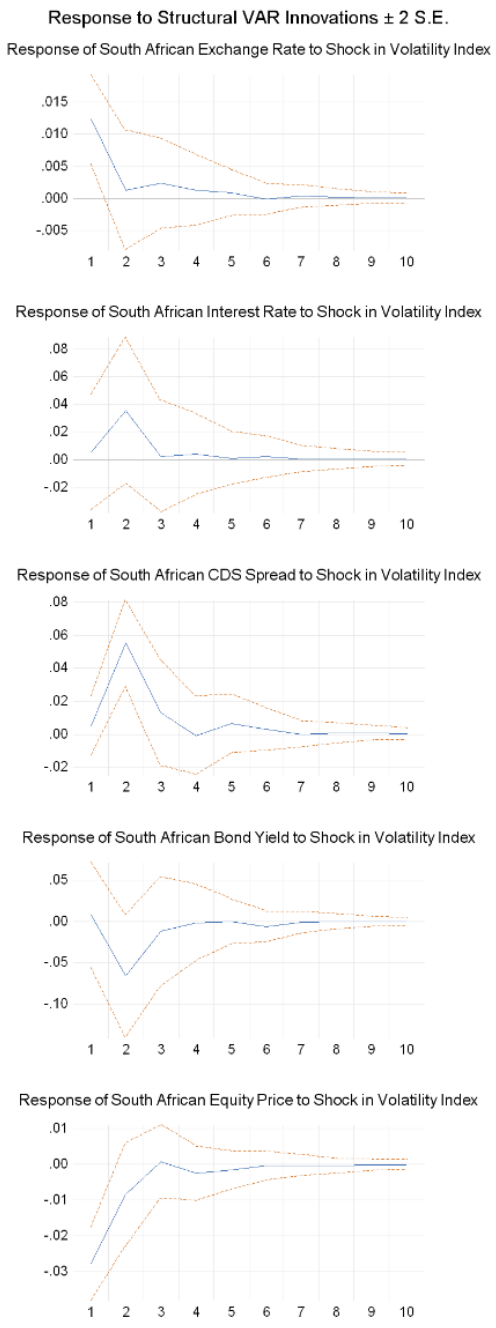


Figure 6: South African Impulse Response Functions

The response of the Rand to a global risk shock is an initial, significant depreciation. The response decreases sharply up to period two and gradually dies out. The response becomes non-significant between periods one and two, and continues as such.

The initial response of the South African interest rate is positive and steeply increases until period two, after which it declines sharply to period three and gradually dies out. This response is, however, not statistically significant throughout, and thus cannot support our analysis.

We observe an initial positive response to the global risk shock in the South African CDS market, again indicating a deterioration in financial conditions. The error bands indicate that this response may not be statistically significant, appearing to extend marginally below the x-axis. This, however, quickly corrects with a steep increase up to period two, indicating statistical significance in the

CDS spread increase. The response then steeply declines, becoming non-significant around period three, and gradually dies out.

The response of the South African government bond yield is initially almost zero. This is followed by a steep decrease to a negative response in period two, which could be explained through the aforementioned safe haven argument. The yield response subsequently increases steeply for a period before gradually dying out. This impulse response function is, however, not statistically significant throughout, and thus cannot be considered in our results.

The South African equity market exhibits a significant, negative initial response to the global risk shock. Subsequently, the equity price steeply increases up to period three and gradually dies out. The response becomes non-significant between periods one and two and continues as such.

We thus observe the expected negative economic and financial reactions in the South African market to a deterioration in global risk sentiment with significant currency depreciation, CDS spread increases and equity price drops. The bond market response as well as the interest rate response are, again, not statistically significant and thus cannot be considered in our results.

6.6. Initial Impulse Responses

A further means of analysing the response of each variables to a global risk shock is to consider the immediate (i.e. period one) response of each of the variables to the shock. We present this in column chart format grouped both by country as well as by type of variable, for ease of comparison.

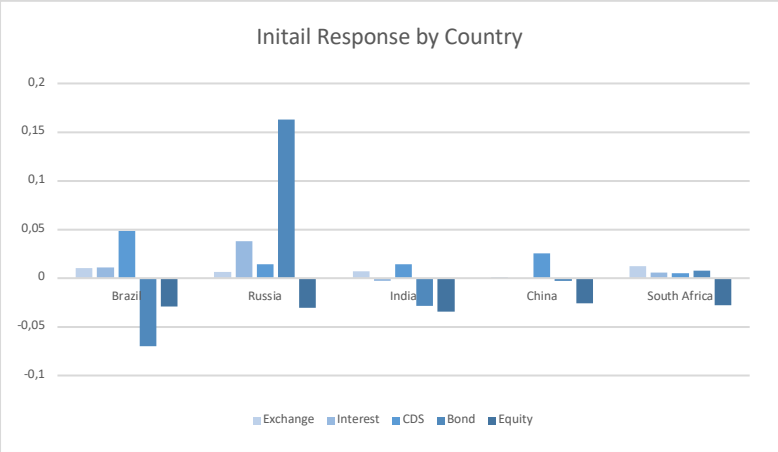


Figure 7: Initial Impulse Response by Country

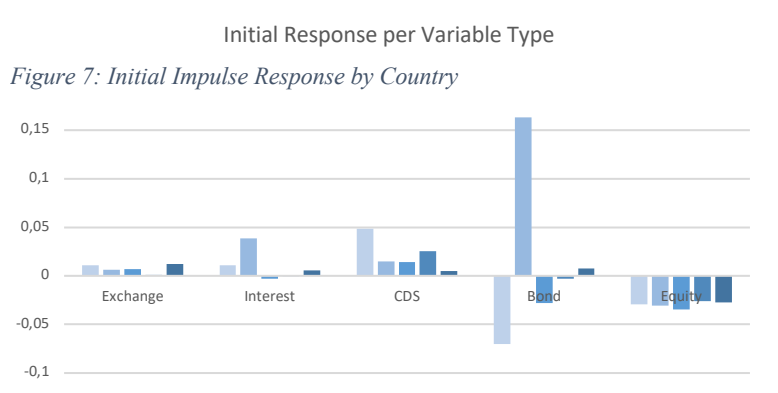


Figure 8: Initial Impulse Response by Variable Type

We observe that, following a global risk shock, the Russian and Brazilian markets face the most pressure, identifiable by the greater magnitude of initial responses in macroeconomic and financial variables. We notice fairly consistent responses across the BRICS in exchange rates and equity prices. The discrepancy in exchange rate responses with China's essentially zero result could be due to the Chinese Yuan being pegged to the US Dollar by the Chinese Central Bank. We further notice a difference in the magnitude of initial responses of the significant impulse responses, with CDS spreads and equity market responses appearing to be greater than interest rate responses.

We observe discrepancies in the interest rate responses as well as the government bond yield responses. The discrepancies in interest rate responses are likely due to interest rates

serving as a monetary policy tool of central banks in domestic economies and are thus artificially manipulated to attain monetary policy objectives. The manually adjusted nature of these rates results in a delay in response to global financial occurrences, and in a level of measuring responses to maintain policy objectives and rational expectations within domestic economies. We cannot rely on these results, however, as they are not significantly different to zero at the 95% confidence level.

The response discrepancies in government bond yields are likely due to the behavioural differences in the various BRICS. The initial response of Russian bonds to a global risk shock is expected, though highly significant, resulting in increased yields and thus a decrease in the price of government bonds. This is indicative of the deteriorating economic conditions in Russia. A similar response is observed by the response of South African government bond yields; however, this response is considered non-significant. The initial response of Brazil, India and China is a decline in government bond yields, which indicates an increase in bond prices. This response would generally be considered unexpected, but may be rationalised, as mentioned earlier, by investors in these countries seeking stable investments with guaranteed returns, thus opting for these government bonds due to their highly stable nature. The response of Chinese bonds is, however, negligible. Again, we cannot reliably utilise the results for Brazil, India, China and South Africa to support our findings as they are not statistically significant at the 95% confidence level.

6.7. Summative Results

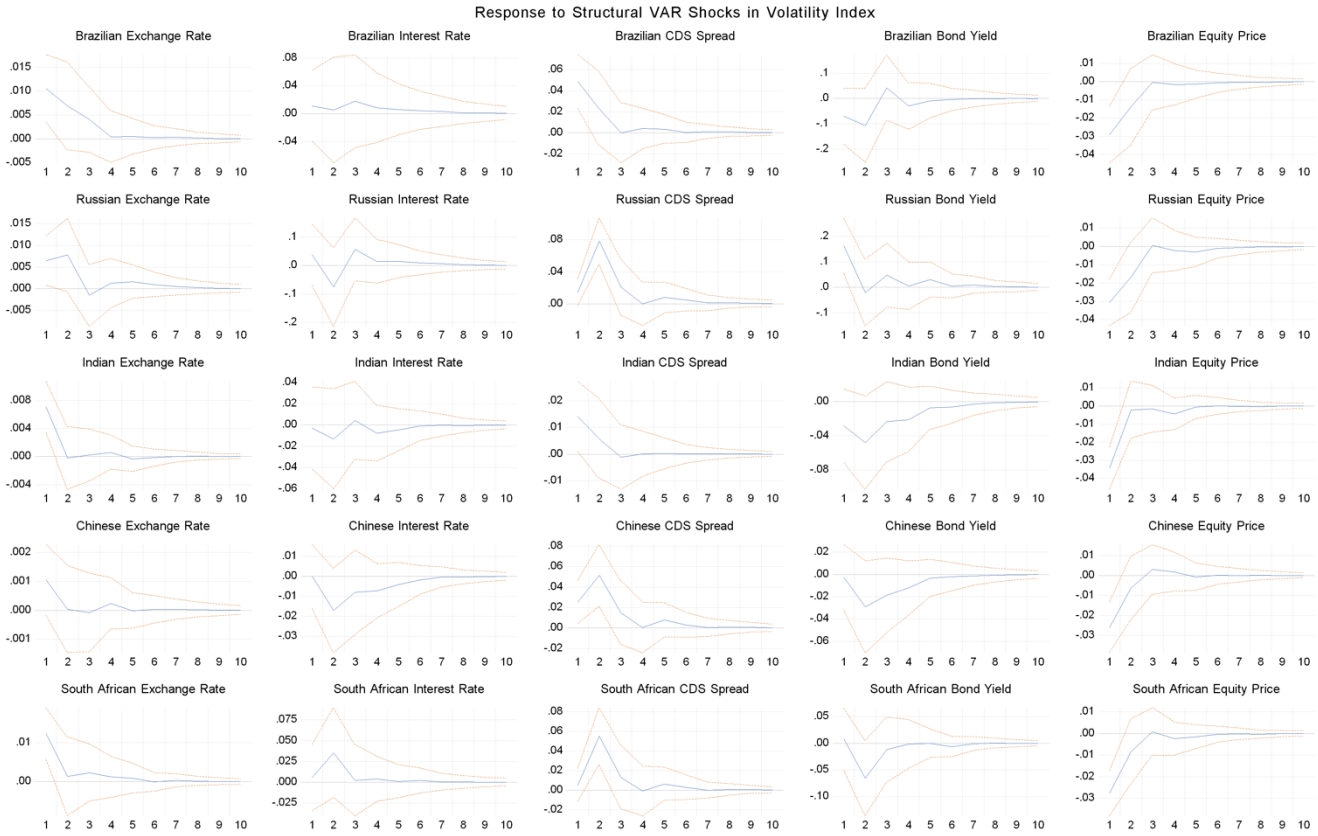


Figure 9: All Impulse Response Functions to Global Risk Shock

It is apparent from the data and our analysis that the immediate effect of a global risk shock on the BRICS economies varies by variable in terms of magnitude and significance. The effects also vary greatly by country in terms of CDS spreads and government bond yields.

A global financial risk shock is observed to have a statistically significant effect on all five BRICS economies in terms of exchange rates (with the exception of the pegged Chinese Yuan), CDS spreads and equity prices. We notice a positive effect on exchange rates, signifying a currency depreciation in each country following a risk shock. The effect on CDS spreads is also positive for all countries, indicating that a risk shock results in a

decline in domestic market conditions in each country. Finally, we observe a negative effect on equity prices following a global risk shock in each country, indicating a deterioration in domestic equity markets. The statistical significance of the impulse responses of all three of these variables due to a global risk shock indicates the deterioration of each domestic economy being linked to a decline in global risk sentiment and is thus indicative of the spread of contagion effects from developed economies to the BRICS.

The responses of the interest rates and bond yields across the BRICS, as discussed previously, contain discrepancies and are thus difficult to interpret reliably without conjecture. These results, however, are not statistically significant, as indicated by the error bands in our impulse response functions. We therefore cannot reliably utilise these responses in our interpretation of results. The clear exception to this non-significance, however, is that of Russian government bond yields which illustrate a significant positive response in the bond yields. This is consistent with our theoretical expectations, with a global risk shock resulting in deteriorated market conditions and thus an increase in bond yields and a decrease in bond prices. This exception further supports our result of the spread of contagion effects from developed economies to those of the BRICS.

6.8. Model Robustness Analysis

The objective of this section is to assess the SVAR model in terms of robustness. We aim to determine whether changes to the model will affect the results analysed previously; namely, global risk shocks exerting a significant effect on exchange rates, CDS spreads and equity prices in each of the BRICS (besides exchange rates in China), while the effects on interest rates and bond yields in each of the BRICS is not seen to be statistically significant (with the exception of bond yield responses in Russia being significant). We also aim to assess whether the magnitude of these responses is affected by country and variable.

The factors that we will alter in the model, *ceteris paribus*, in an effort to investigate its robustness are the sample period, the measure of global risk, and the identification scheme. The results of these robustness checks are detailed below.

6.9. Robustness Analysis: Sample Period

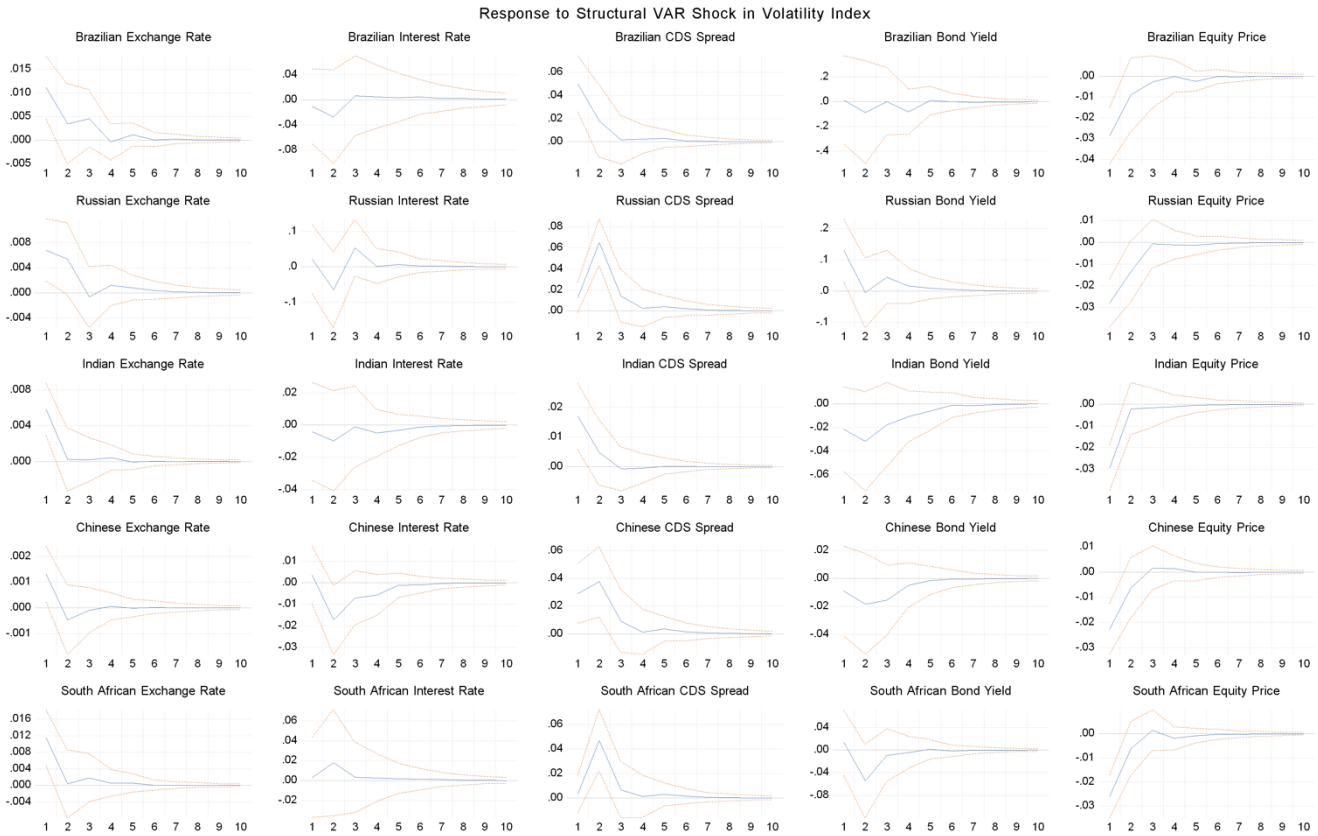


Figure 10: Impulse Response Functions to Robustness Test of Alteration of Sample Period

In an effort to assess the robustness of our model over time, we alter the sample period of the data, *ceteris paribus*, before estimating the model. We utilise a sample period of January 2002 to December 2019 for this test and analyse the impulse response functions for this period.

The impulse response functions indicate that our findings remain relatively unchanged with extremely similar responses in each function to a global risk shock, as well as the same result of statistical significance and non-significance in every case, as the results of the original time period analysed. From these results, we conclude that the model is robust

in relation to changes in the sample period, with very similar responses being exhibited over the extended period.

6.10. Robustness Analysis: Measure of Global Risk

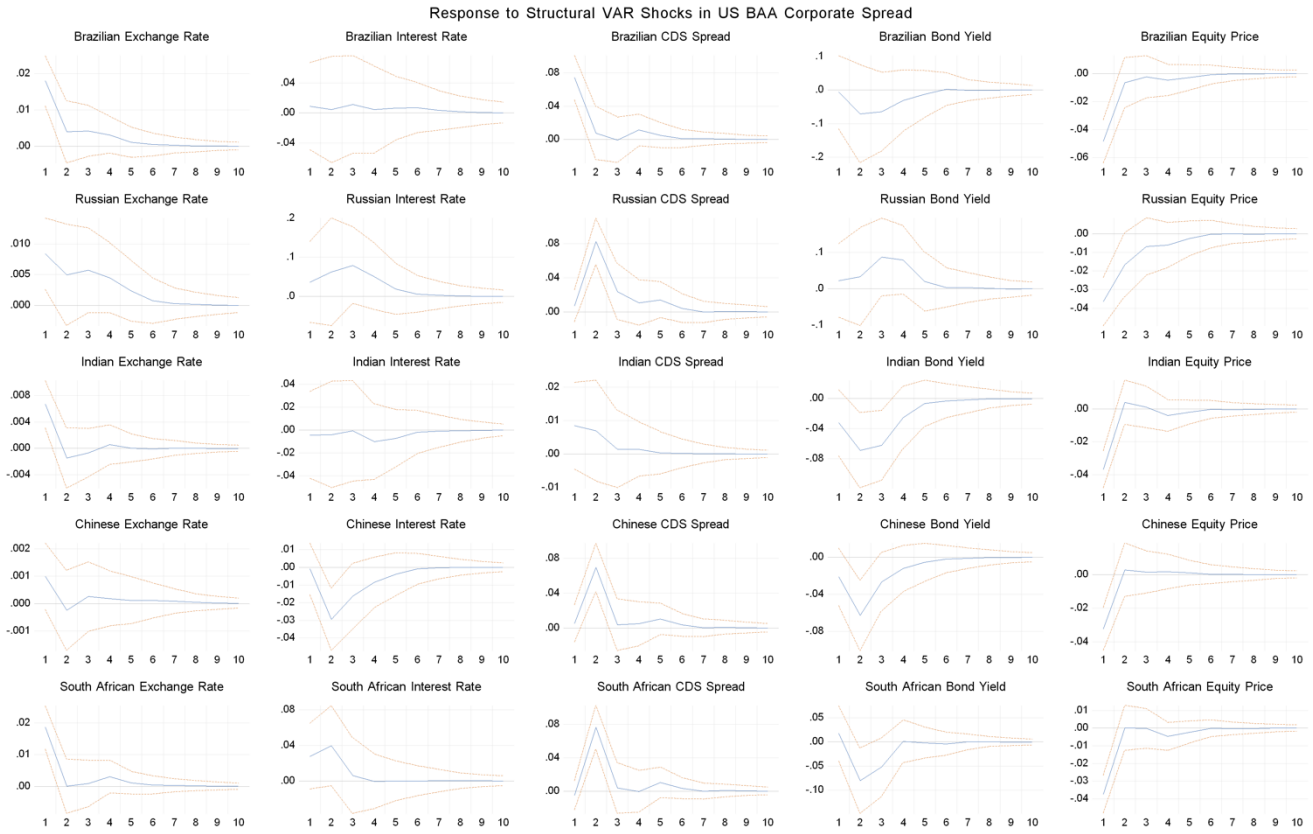


Figure 11: Impulse Response Functions to Robustness Test of Alteration of Global Risk Measure

In this analysis, the measure of global risk is altered, *ceteris paribus*, in an effort to gauge the robustness of the model. We utilise the US Baa corporate spread as the proxy of global risk appetite as opposed to the Volatility Index, similarly to Yildirim (2016), and analyse the resulting impulse response functions.

We observe fairly similar response functions to those resulting from the original analysis. The major differences noted are, firstly, the non-significance of the Indian CDS spread and Russian bond yield response functions, as well as the shape of the Russian bond yield response function. This suggests that the negative effects observed in the BRICS economies are fairly similar, regardless of the global risk measure utilised in the model, indicating relative robustness in the model.

6.11. Robustness Analysis: Identification Scheme

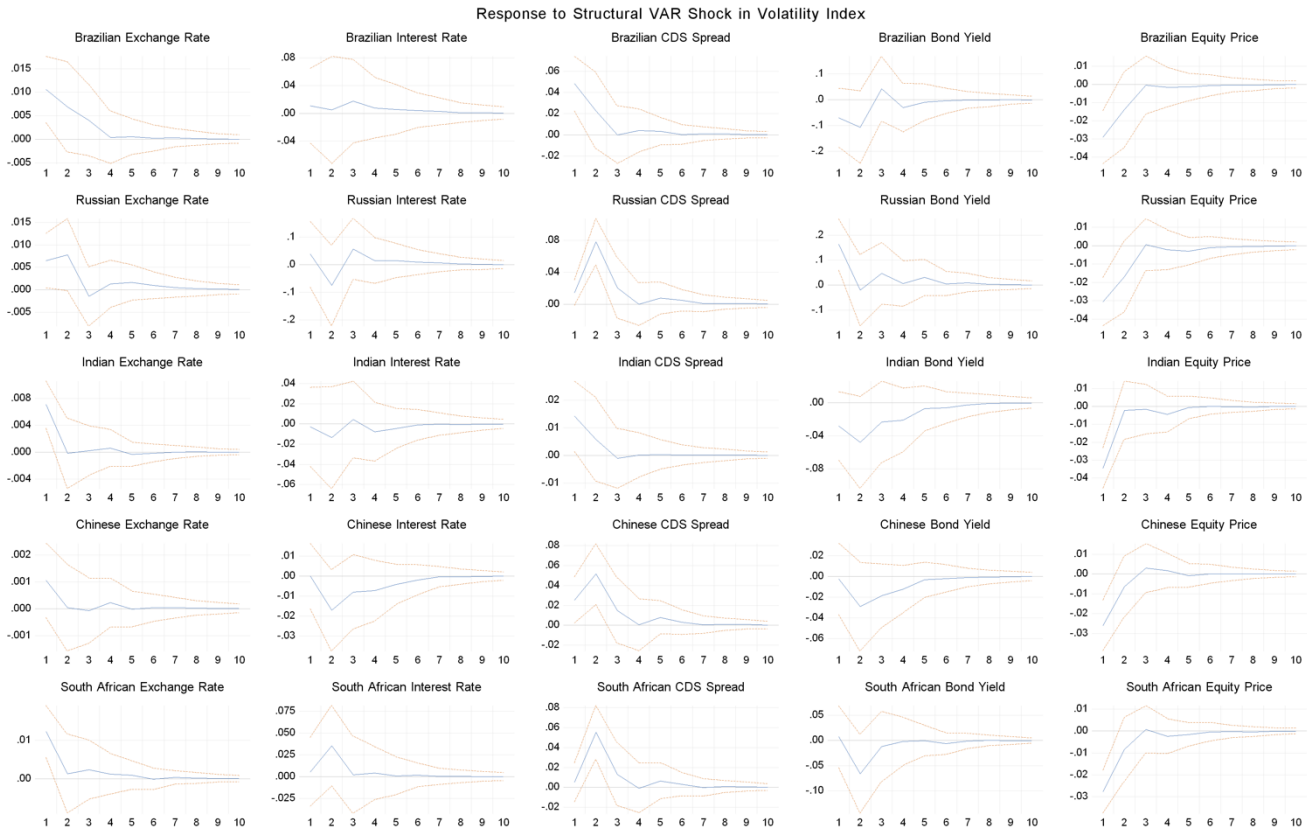


Figure 12: Impulse Response Functions to Robustness Test of Alteration of Identification Scheme

In the estimation of the SVAR model, an objective was to allow for block exogeneity in the global risk measure (as well as the US Federal Fund Rate, proxying US monetary policy). We thus aimed to allow for contemporaneous effects across our domestic

variables. These effects, however, are potentially imperfectly restricted due to the limitations of the Cholesky Decomposition recursive identification scheme utilised to ensure that our model is properly identified in its estimation. In an effort to assess robustness across the identification scheme, we reorder our variables across our scheme as shown below. Note that the order of countries is kept constant due to the openness of each of these countries not being the variable examined.

$$A(0) = \begin{array}{c} \\ \text{FFR} \\ \text{VIX} \\ \text{Equit} \\ \text{Bond} \\ \text{CDS} \\ \text{Int} \\ \text{Exch} \end{array} \begin{array}{c} \begin{array}{ccccccc} \text{FFR} & \text{VIX} & \text{Equit} & \text{Bond} & \text{CDS} & \text{Int} & \text{Exch} \end{array} \\ \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & 0 \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 \end{bmatrix} \end{array}$$

Key	
FFR	= US Federal Fund Rate
VIX	= Volatility Index
Exch	= Exchange Rate
Int	= Interest Rate
CDS	= Sovereign CDS Spread
Bond	= Government Bond Yield
Equit	= Equity Price

Figure 13: A(0) Matrix Specifications for Testing Robustness when Altering Identification Scheme

The results of the change of variable order in the identification scheme indicate that our findings remain almost identical with extremely similar responses in each function to a global risk shock, as well as the same result of statistical significance and non-significance in every case. From these results, we conclude that the effects of a global risk shock on the BRICS economies is essentially identical, regardless of the ordering of variables in the identification scheme, indicating a high level of robustness in the model in this regard.

7. Conclusion

In this study, we aimed to identify whether contagion effects exist by identifying the spread of financial shocks from the global economy to the BRICS economies. This was attempted by implementing a structural vector autoregressive model with block exogeneity. A number of variables were utilised to model our SVAR. In terms of the domestic BRICS markets, the macroeconomic factors used were exchange rates and interest rates and the financial indicators that were utilised were sovereign CDS spreads, government bond yields and the prices of each country's primary equity index. The Volatility Index and the US Federal Fund Rate were utilised as proxies for global factors in the main analysis.

We investigated a sample period consisting of monthly data from January 2005 to December 2018. In order to render a reliable, 'just identified' SVAR, the block exogeneity assumption was implemented using the Cholesky Decomposition recursive identification scheme with the ordering of variables carefully considered. Once the SVAR had been estimated, impulse response functions were simulated, and bootstrapped by 95% confidence intervals generated by utilising a Monte Carlo simulation with 250 repetitions.

Through our investigation, we conclude that global risk shocks induce statistically significant impulse responses in the exchange rates, sovereign CDS spreads and the equity prices in all the BRICS, with the exception of China's pegged exchange rate. Additionally, we further observe a significant response in Russia's bond market.

However, we cannot draw conclusions from the impulse response functions of the BRICS countries' interest rates and the government bond yields (barring Russia) as these responses to a global risk shock appear to not be statistically significant from zero. The

non-significance of the interest rate responses may be due to the fact that interest rates serve as a monetary policy tool which is artificially manipulated by central banks, the revision of which is generally prone to significant lags. As such, we may not use the results of these impulse response functions to support our conclusion.

We can thus conclude from our analysis that the statistical significance of the impulse responses to a global risk shock of exchange rates, CDS spreads and equity prices in each of the BRICS (except exchange rates in China), as well as bond yields in Russia, indicates the deterioration of each of these domestic economies. This is in line with theoretical economic predictions, being linked to a decline in global risk sentiment, and is thus indicative of the spread of contagion effects from the developed global economies to the BRICS.

The robustness checks of the SVAR model in terms of sample period, global risk measure and identification scheme indicate a high level of robustness in the estimated model, which further supports our conclusion of the existence of contagion effects from the global economy to the BRICS economies.

8. Recommendations for Further Study

Through this study and the investigation that led to our final conclusion, we propose several recommendations that could be proposed for further study on this topic.

We begin with yjr data considerations and limitations identified in this study. Firstly, we would suggest conducting this research with data of a daily frequency, as daily data are generally considered to contain more information than monthly data. This may potentially increase the accuracy and reliability of the estimated model. It must be noted, however, that this increase in data frequency would likely require software and hardware of greater processing capacity than EViews 11 and the consumer specification machine utilised in this study, due to the sheer volume of data observations that would need to be processed.

Secondly, we recommend utilising the industrial production index data as a further macroeconomic variable pertinent to the domestic economies in the SVAR model. As mentioned, complete data sets could not be obtained for the purposes of this study, somewhat limiting our analysis from a macroeconomic variable perspective.

The next consideration we address is that of the limitations in the identification scheme of our model due to the limited functionality of EViews 11. Due to the limitations found in the utilisation of EViews 11 as our primary analytical tool, we were bound to the restrictions placed on the parameters of our A(0) matrix to ensure appropriate identification of the SVAR, and thus utilised the Cholesky Decomposition as a somewhat effective, though imperfect solution. We recommend, in further study, the use of more robust statistical software, such as RATS, in the estimation of the SVAR. Such software would allow for estimation of far more complex Bayesian VARs, permitting freedom of restrictions placed on the A(0) matrix parameters and thus providing a means to allow the

modelling of all contemporaneous relationships suggested by economic and financial theory.

Our final recommendation would be, along with the software recommendations already proposed, the ability to dynamically adjust parameter restrictions, in order to analyse the impulse responses of shocks in individual domestic markets variables on the other remaining BRICS markets, as well as on the measure of global risk. This would allow us to assess whether these shocks are unidirectional or whether emerging market shocks do affect the economies of other emerging markets, as well as the global market, thus purporting the existence of multidirectional contagion.

9. References

Allen, F. & Babus, A. (2008) *Networks in Finance.* Wharton Financial Institutions Center Working Paper No. 08-07.

Baldwin, R. & Giavazzi, F. (2015). The Eurozone Crisis. A Consensus View of the Causes and a Few Possible Solutions. London, UK: Centre for Economic Policy Research Press.

Bekaert, G., Ehrmann, M., Fratzscher M. & Mehl, A. (2014). The Global Crisis and Equity Market Contagion. *The Journal of Finance, 69*(6), 2597-2649.

Bonga-Bonga, L. (2018). Uncovering equity market contagion among BRICS countries: An application of the multivariate GARCH model. *The Quarterly Review of Economics and Finance, 67*, 33-44.

CBOE. (2020). CBOE VIX. Turn Volatility to Your Advantage. Accessed 14 January 2020, from: http://www.cboe.com/vix

Chan-Lau, J.A., Mathieson, D.J. & Yao, J.Y. (2004). Extreme Contagion in Equity Markets. *IMF Staff Papers 51*(2), 386-408.

Corwin, S.A. & Coughenour, J.F. (2008). Limited Attention and the Allocation of Effort in Securities Trading. *The Journal of Finance, 63*(6), 3031-3067.

Cover Design Vectors. [JPEG]. Freepik. Retrieved 10 March 2020, from: http://www.freepik.com/

Dungey, M. & Gajurel, D. (2014). Equity market contagion during the global financial crisis: Evidence from the world's eight largest economies. *Economic Systems, 38*(2), 161-177.

Elliott, M., Golub, B. & Jackson, M. O. (2014). Financial Networks and Contagion. *The American Economic Review, 104*(10), 3115-3153.

Forbes, K. & Rigobon, R. (2001). Measuring Contagion: Conceptual and Empirical Issues. In: Claessens, S. & Forbes, K.J. (Ed.), *International Financial Contagion*, 43-66. Boston, MA: Springer.

Frank, N. & Hesse, H. (2009). *Financial Spillovers to Emerging Markets During the Global Financial Crisis,* IMF Working Paper No. WP/09/104.

Glasserman, P. & Young, H.P. (2015). How likely is contagion in financial networks? *Journal of Banking & Finance, 50*(C), 383-399.

Hall, P. (1988). On Symmetric Bootstrap Confidence Intervals. *Journal of the Royal Statistical Society, B50*, 35-45.

Horvath, R. (2008). How Important are Foreign Shocks in Small Open Economy? The Case of Slovakia. William Davidson Institute Working Paper No. 933.

IMF. (2013). *Global Financial Stability Report. Transition Challenges to Stability*. Accessed 15 January 2020, from: https://www.imf.org/External/Pubs/FT/GFSR/2013/02/

Kudlacek, S. (2008). The Interest Rate and Related Macro Economic Variables, Notes. Analysis of the government bond market and monetary policy. Akelius

University. Retrieved 13 January 2020, from: https://university.akelius.com/library/pdf/the_intere_kudlacek_s0904.pdf

Leitner, Y. (2005). Financial Networks: Contagion, Commitment, and Private-Sector Bailouts. *The Journal of Finance, 60*(6), 2925-2953.

Mondria, J. & Quintana-Domeque, C. (2006). Financial Contagion Through Attention Reallocation: An Empirical Analysis. *SSRN.* Available online at: https://ssrn.com/abstract=957185

Mondria, J. & Quintana-Domeque, C. (2013). Financial Contagion and Attention Allocation. *The Economic Journal, 123*(568), 429-454.

Nishat, M. & Ullah, W. (2017). *Analysis of the government bond market and monetary policy*. International Growth Centre. Accessed 15 January 2020, from: https://www.theigc.org/project/analysis-of-the-government-bond-market-and-monetary-policy/

Ozcelebi, O. (2018). *Impacts of Exchange Rate Volatility on Macroeconomic and Financial Variables: Empirical Evidence from PVAR Modelling*. IntechOpen. Retrieved 7 January 2020, from: https://www.intechopen.com/books/trade-and-global-market/impacts-of-exchange-rate-volatility-on-macroeconomic-and-financial-variables-empirical-evidence-from

Pesaran, M. H. & Pick, A. (2004). *Econometric Issues in the Analysis of Contagion.* CESifo Working Paper No. 1176.

Prabha, A.P., Barth, J.R. & Kim, H. (2009). Spillover Effects from the U.S. Financial Crisis: Some Time-Series Evidence from National Stock Returns. In: Gup, B.

(Ed.), *THE FINANCIAL AND ECONOMIC CRISES: AN INTERNATIONAL PERSPECTIVE*. Cheltenham, UK: Edward Elgar Publishing.

Pratama, I., Permanasari, A., Ardiyanto, I. & Indrayani, R. (2016). A review of missing values handling methods on time-series data. *2016 International Conference on Information Technology Systems and Innovation (ICITSI)*. Accessed 16 January 2020, from: https://www.researchgate.net/publication/313867740_A_review_of_missing_values_handling_methods_on_time-series_data

Roukny, T., Bersini, H., Pirotte, H., Caldarelli, G. & Battiston, S. (2013). Default Cascades in Complex Networks: Topology and Systemic Risk. *Scientific Reports, 3*(2759) doi:10.1013/srep02759.

Stiglitz, J.E. (2010). *Risk and Global Economic Architecture: Why Full Financial Integration may be Undesirable.* National Bureau of Economic Research Working Paper No. 15718.

Summer, M. (2013). Financial Contagion and Network Analysis. *Annual Review of Financial Economics, 5*(1), 277-297.

Tabarraei. H. (2014). *Euro-Crisis and Spillover Effects on the Emerging Economies.* Paris School of Economics Working Paper No. 2014-07.

Tedeschi G., Mazloumian A., Gallegati M. & Helbing D. (2012). Bankruptcy Cascades in Interbank Markets. *PLOS ONE* 7(12):e52749. doi:10.1371/journal.pone.0052749.

Viale, A.M., Bessler, D.A. & Kolari, J.W. (2014). Equity market contagion during the global financial crisis: Evidence from the world's eight largest economies. *Journal of Applied Economics, 17*(2), 373-400.

Yildirim, Z. (2016). Global Financial Conditions and Asset Markets: Evidence from Fragile Emerging Economies. *Economic Modelling, 57*(1), 208-220.

Appendix A

Country/Financial Variable			Brazil	Russia	India	China	South Africa
Domestic Block	Macroeconomic Variables	Interest Rate	Banco Central Do Brazil	Federal Reserve Bank of St. Louis - FRED	Federal Reserve Bank of St. Louis - FRED	Federal Reserve Bank of St. Louis - FRED	South African Reserve Bank
		Exchange Rate	Yahoo! Finance	Yahoo! Finance	Yahoo! Finance	Yahoo! Finance	Yahoo! Finance
	Financial Variables	5 Year Soeverign CDS Spread	Bloomberg Terminal	Bloomberg Terminal	Bloomberg Terminal	Bloomberg Terminal	Bloomberg Terminal
		5 Year Government Bond Yield	Federal Reserve Bank of St. Louis - FRED	Federal Reserve Bank of St. Louis - FRED	Federal Reserve Bank of St. Louis - FRED	Federal Reserve Bank of St. Louis - FRED	Federal Reserve Bank of St. Louis - FRED
		Equity Price	Bloomberg Terminal	Bloomberg Terminal	Bloomberg Terminal	Bloomberg Terminal	Bloomberg Terminal
Global (External) Block	Primary Global Risk Proxy	Volatility Index	Chicago Board Options Exchange - VIX Index				
	US Monetary Policy Proxy	US Federal Fund Rate	Federal Reserve Bank of St. Louis - FRED				
	Secondary Global Risk Proxy	US BAA Corporate Spread	Federal Reserve Bank of St. Louis - FRED				

Table 2: Data Sources

