The effects of oil prices on equity market returns in BRICS grouping: A quantile-on-quantile approach

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ABSTRACT

This study assesses the effects of the magnitude of oil price shocks i.e. large negative, positive and moderate oil price shocks on equity market returns in BRICS countries during different market circumstances by making use of quantile-on-quantile regression. The current study differs from studies that employ quantile-on-quantile in assessing the relationship between oil price shocks and equity returns in different aspects. Firstly, the study intends to assess how this relationship differs per countries given their factor endowment (i.e. whether they export or import oil) within the BRICS grouping. Secondly, we also differ from Sim Zhou (2015) and Tchatoka et al. (2018) because we introduce the supply shocks by following the same structure as Kilian and Park (2009) but changing the Cholesky decomposition by ordering real oil price first, assuming the contemporaneous response of global production to oil price. The results of the empirical analysis show that distinction should be made between the demand-driven and supply-driven oil price shocks and that the outcome of this relationship depends on whether a country is a net importer or exporter of crude oil. For most of the net oil-importing countries, the low oil price demand shocks, which translate to lower oil prices, further stimulate equity markets when they are at peak. And for oil-producing countries in general, high demand oil price shocks provide an incentive for the expansion of equity markets during bad market conditions.

1. Introduction

The relationship between oil prices and equity market returns is of great interest to policymakers, economists and investors, alike. This is because oil is one of the most valued commodities in the world and a commodity the global economy cannot function efficiently without. Sudden price changes can affect the global economic system, from household expenditure, to firms' earnings and the nation's GDP. Furthermore, oil price movements are susceptible to policy changes, news and world markets fluctuations. Therefore, it is important that policymakers and investors understand the link between oil price shocks and equity market returns.

The cost of production is one of the important channels through which oil prices affect equity market returns. Higher oil prices lead to higher costs in production of goods and services due to the relative price of energy inputs in the production process. This in turn puts pressure on firms' profit margins and consequently, negative valuation of assets.

A number of studies show that positive oil price shocks lead to high costs of production and consequently, high inflation, which is detrimental to the performance of the equity market returns (Balcilar et al., 2018; Salisu et al., 2017; Cologni and Manera, 2008). Earlier studies document a negative association between the change of oil prices and equity market returns (Jones and Kaul, 1996 and Sadorsky 1999). These studies show that oil price hikes have a negative effect on equity market returns. For example, Jones and Kaul (1996) examine the link between equity market returns and oil prices and show that oil price hikes affect the equity markets of four developed economies namely U.S., U.K., Canada and Japan negatively.

Very few studies sought to analyse the impact of oil price changes on equity market returns in emerging economies. For example, Fang and You (2014) sought to find the link between oil prices and equity returns of three emerging markets (Russia, India and China) utilizing a structural vector autoregressive model. Their results varied, showing that India's equity market returns respond positively only to oil price shocks specific to India's demand. In other words, equity market returns of India only respond positively to oil price shocks that are associated with India's demand for oil. Otherwise, India's equity market returns respond negatively to other oil price shocks. For Russia, while the findings show that oil-specific supply shocks strengthen equity market returns of Russia, oil-specific demand shocks suggest the reverse. For Chang and You (2014), China equity market returns respond negatively to oil price shocks driven by China's demand for oil. Overall, the authors show that the effects of oil price shocks on equity market returns are conditional on whether the countries are importers or exporters of oil, such as China and Russia respectively. However, the study does not account for the different states of equity markets.

Recent studies show that the relation between equity market returns and oil price shocks may be asymmetric (Yildrim et al., 2018; Reboredo and Ugolini, 2016; Zhu et al., 2016; Sim and Zhou, 2015; Cunado and Gracia, 2005). For example, a Markov Switching Vector Autoregressive model is employed by Yildrim et al. (2018) to account for asymmetries in the relationship between BRICS equity market returns and oil prices and find that responses differ for each regime. For instance, equity market returns will have a positive response to oil-price shocks in high mean-low volatility regimes and negatively to low mean-high volatility regimes. This shows that the effect of an unexpected change in oil prices on equity returns may differ when the market is in a bearish state compared to when they are in a balanced or bullish state. However, very few studies have analysed how the relationship between oil price shocks and equity market returns vary according to their respective quantiles. In addition, very few studies that assess the effects of oil price shock on equity market returns relying on quantile dependence focus on emerging economies, in particular the BRICS countries (Reboredo and Ugolini, 2016; Tchatoka et al., 2018). BRICS countries are among the most important emerging economies given their geopolitical and economic influence. The particularity of the BRICS grouping is that it combines countries that are either the biggest suppliers or demanders of resources and commodities such as oil. It is thus important to analyse how unexpected change in oil price affects equity returns when accounting for countries' resource endowment.

The current study assesses the effects of different oil price shocks on equity market returns in BRICS countries across all market circumstances. Specifically, the study intends to assess how this relationship differs per countries given their factor endowment (i.e. whether they export or import oil) within the BRICS grouping. To achieve this, the current study adopts a methodology similar to Sim and Zhou (2015) and apply the technique to BRICS grouping. Although the current study may appear to be remarkably similar to Tchatoka et al. (2018), it differs to both Sim and Zhou (2015) and Tchatoka et al. (2018) because we introduce the supply shocks in our analysis following the same structure as Kilian and Park (2009) but changing the Cholesky decomposition by ordering real oil price first, assuming the contemporaneous response of global production to oil price. This study will be able to assess what the magnitude of equity return would be when the equity market is in the lower quantile (bearish) and the oil price is in the higher quantile (big unexpected change in oil price). To achieve the current study's objective, firstly, we employ a SVAR (Structural Vector Autoregression) to identify oil supply and demand shocks. Then, after identifying each of these shocks, we employ a quantile-on-quantile regression to assess how the size of oil shocks categorised from the quantile distribution affect the different states of equity markets in BRICS economies.

The results of the empirical analysis discussed in the current study on the correlation between oil-price shocks and the performance of equity returns, show that the asymmetry of this relationship may be further understood by distinguishing between the state of the equity market of the distribution of oil-price shocks. In addition, distinction should be made between demand-driven and supply-driven oil price shocks and that the outcome of this relationship depends on whether a country is a net crude oil exporter or importer. For most of the countries that are net oil-importers, the low oil price demand shocks, which translate to lower oil prices, further stimulate equity markets when they are at peak. And for oil-producing countries in general, high demand oil price shocks provide an incentive for the expansion of equity markets during bad market conditions. Furthermore, the results show that higher oil prices provide an incentive for BRICS stock markets to surge during periods of turmoil. Another similarity is that higher demand shocks have negligible impact on BRICS equity market returns when the market conditions are good.

2. Literature review

A number of studies have attempted to assess the relationship between equity market returns and oil prices. For example, in a seminal study, Jones and Kaul (1996) examine the relationship between equity market returns and oil price in four developed economies, namely the U.S., U.K., Canada and Japan. The authors use a standard cash-flow model following the assumption that oil price shocks are relevant for changes in equity market returns because they affect current and future real cash flows and expected returns. Their results show that US and Canadian equity prices react to oil price shocks following an impact of the oil shock on real cash flows. However, for the U.K. and Japan the results suggest that oil price shocks account for larger changes on equity market prices compared to real cash flows.

Following this study, many studies sought to examine the link between oil prices and equity market returns. Sadorsky (1999), relying on monthly data from 1947 to 1996, utilises an unrestricted vector autoregressive model. The author identifies shocks in the VAR system by using Choleski factorisation and orders the variables by placing the 3-month Treasury bill rate as the first variable, followed by oil price volatility obtained from the GARCH model, industrial production and equity market returns. Findings show that positive oil price shocks have a negative bearing on real equity market returns in the US economy.

Miller and Ratti (2009) use a cointegrated vector error correction model with additional regressors to investigate the long-run relationship between oil prices and the equity market returns of six OECD countries (France, Germany, Canada, Italy, the U.K. and the US). They use data spanning from 1971 to 2008. Their model also allows for endogenously identified breaks and show evidence for breaks after 1980:5, 1988: 1 and 1999: 9. Moreover, they show that there is a long-run relationship for periods 1971:1 to 1980.5 and 1988:2 to 1999.9. Their findings suggest that equity market returns respond negatively to a rise in oil prices over the long-run. However, the relationship tends to disintegrate after 1999.9, supporting the notion that the relationship between equity market returns and oil prices has changed in recent years compared to the past decades.

Ono (2011) sought to study the effects of oil price changes on equity market returns of BRICs. The study employs a multivariate VAR model using monthly data set from 1999 through to 2010. The author uses three variables: oil prices, equity returns and industrial production. Oil prices used in the model include three indicators of oil: OP (calculated as changes in the oil price), SOP (scaled oil price) and NOPI (net oil price increase). The study documents that equity market returns of BRICs, except Brazil, respond positively to some of the oil price indicators. However, when taking into consideration spill over effects from the New York Stock Exchange, India's equity returns respond positively to OP and negatively on SOP. Regarding the variance decomposition analysis, while the results show that the impact of oil price shocks to the volatility of equity market returns of China and Russia is statistically significant, they do not show any significance for India and Brazil.

Dagher and Hariri (2013) examines the dynamic linkages between equity market returns of the Lebanese and oil price within the framework of VAR along with the impulse response and variance decomposition analysis. The study relies on daily data from October 2006 through to July 2012. Based on the Granger causality tests, there is evidence that suggests that oil prices affect equity market prices of Lebanon. Secondly, the impulse response function results suggest that equity market prices of Lebanese respond positively to oil price shocks and dissipates from the second day onwards. Although the prior results from the study suggest that equity market prices of Lebanon respond positively to oil price shocks, the variance decomposition analysis implies that the forecast errors of the equity price are largely ascribed to their own innovations. In brief, the study concludes that equity markets of Lebanon do not respond largely to oil-price shocks.

While some studies assume linearity when assessing the correlation between oil prices and equity market returns, like those already discussed above, other literature focus on investigating the non-linear relationship. Nonlinearity is important in assessing the relationship between oil prices and the performance of equity markets, as a decrease or increase in the price of oil may have asymmetric effects on the performance of equity markets. Ciner (2001) examines the between oil price changes and the US stock index by using heating oil and crude oil futures prices. The author relies on nonlinearity tests within the context of a bivariate VAR model and applies the test on a residual series obtained from the estimated bivariate VAR model. The author uses daily closing prices of oil futures contract and S&P 500 data ranging from 1979 for heating oil futures and 1983 for crude oil futures prices through to 1990, 16 March along with the S&P 500 stock index. The author arrives at two main findings. Firstly, Ciner (2001) finds that there is a non-linear feedback relationship between oil prices and the US equity market. Secondly, the results suggest that the linkage between oil prices and equity market returns is stronger in the 1990s.

Reboredo (2010), following a Markov-Switching approach, investigates whether oil price shocks impact equity market returns of Netherlands, the UK, the US, and Germany nonlinearly. The model allows the regression coefficient and the variance to be conditioned to a specific state. The author makes use of monthly data from the S&P 500 for US, FTSE for the UK, DAX for Germany and AEX for Netherlands. Oil price shocks are measured using Brent crude, West Texas Intermediate and Dubai oil prices. However, the study only focused on the results for Brent. The outcomes imply that a rise in the oil price impacts equity market returns of the four countries negatively. And while the impact is significant one regime, the results show that the effect is insignificant in another regime. According to Reboredo, the difference is due to levels of uncertainty in the equity market. For instance, in a situation where there is too much uncertainty in the equity market, the impact of oil price shocks tends to be significant than when uncertainty was low.

Still in showing the importance of an asymmetric relationship between equity market returns and the change in oil prices, Yildirim et al. (2018) investigates the dynamic relationship between oil prices and equity returns of BRICS, using monthly data from 1995 to 2016. The study employs a Markov-Switching Vector Autoregressive model and shows that the response of equity market return of BRICS to oil price shocks varies over regimes (low mean-high volatility regime and high mean-low volatility regime) for each country (see Yildirim et al., 2018, page 1715). While the results indicate that the response of equity market returns to oil price shocks is positive in both cases for the BRICS bloc, in some instances the responses are statistically insignificant.

When looking at the Brazilian stock market, the response is statistically significant in the high mean-low volatility regime, while for India it is in the low mean-high volatility regime. This implies that equity markets respond to oil price shock positively, but the response depends on the state of the equity market. Lee and Chiou (2011) sought to examine the asymmetric effects of oil price shock on the returns of the US equity market by making use of a regime switching model and the ARJI model to account for jumps. They used data spanning from 1992 to 2008. Their results suggest that significant (large) fluctuations affect the US stock market returns negatively. However, this result only holds in regimes with higher oil prices compared to those with lower oil prices. This implies that only extreme positive oil price changes influence the US stock market. Zhu et al. (2011) investigate the relationship between real crude oil shocks and real stock market prices for OECD and non-OECD panel using monthly data spanning from 1995 to 2009. The authors utilise a panel threshold vector error correction model and conclude that the adjustment towards long-run equilibrium between the two variables is asymmetric. Overall, the results show that there is a bidirectional relationship and that high oil price shocks impact stock prices positively in the long-run and that a surge in stock prices also affects oil prices positively in the long-run.

Tsai (2015) sought to uncover if oil price shocks have any asymmetric effects on equity market returns by investigating whether those of the US respond the same way to oil price shocks before, during and after the financial crisis. To this end, the author relies on firm-level daily data ranging from January 1990 to December 2012. To estimate the effect of negative and positive oil price shocks, the study follows an OLS approach with panel corrected standard errors. Furthermore, to differentiate between the financial crisis and post-crisis periods, the study uses two dummy variables. The findings show that during the financial crisis and after, equity market returns respond heterogeneously to oil price changes. In fact, the results confirm that industries that are more energy-intensive respond positively to oil price shocks compared to less energy-intensive manufacturing industries. When focusing on firm size, the results suggest that big firms were more negatively affected by oil price shocks before the financial crisis. Conversely, the influence of an oil price shock on medium-sized firms is more positively amplified after the financial crisis.

Mensi et al. (2016) examines the dependence structure between oil prices and equity market returns of developed equity markets. The authors focus on four regions, namely, Canada, the US, Europe and the Pacific (excluding Japan). To examine the dependence, the study relies on a combination of static and time-varying symmetric and asymmetric copula functions and VMD (variational mode decomposition) method. The dependence structure is analysed across all market circumstances, i.e. bear, balanced and bull markets under two different time horizons. The authors use daily data starting from 4 June 1998 through to 6 May 2016. The results show evidence of tail dependence between oil prices and equity market returns of the four regional markets. Moreover, the results show evidence of tail dependence in long-run horizons, except the S&P 500 Index which shows an average dependence. In the short-run horizons, dependence is evidenced across all regional markets.

Very few studies have employed quantile regression to explain the asymmetric relationship between the change in oil prices and equity market returns. Lee and Zeng (2011) examine the effect of changes in oil prices on equity market returns of G7 countries. The study uses monthly data ranging from 1968 to 2009 and employs a quantile regression to estimate the asymmetric relationship between oil prices and equity market returns. Their findings were that significant dependence exists in the lower and upper quantiles. In addition, they conclude that oil price movements impact most of the G7 countries' equity market returns negatively.

Zhu et al. (2016) sought to uncover the asymmetric relationship between oil prices and stock prices by taking into consideration various quantiles of oil price shocks. Their study relies on monthly data spanning from 2001 to 2015. The authors applied an econometric technique that uses a quantile regression to estimate a SVAR model and found that the responses of China's equity market return to oil price shocks depends on whether the oil price shock is in the lower or upper quantile as well as the nature of the oil price shock (demand driven or supply driven). Moreover, the results show that the Chinese equity market returns deteriorate when demand and supply oil price shocks decrease rapidly. However, the results also show that during a boom period, demand-driven oil price shocks boosts Chinese equity market returns.

Nusair and Al-Khasawneh (2018) also applied a quantile regression to estimate the relationship between oil price changes on equity market returns of GCC (Gulf Cooperation Council countries). The authors use daily data from Thomson Reuters spanning from 2004 to 2016. Their finding is that there are asymmetric effects from oil price shocks to GCC equity market returns as the results show that large positive oil price changes impact equity market returns positively when the equity market is in a bullish state or a normal state. But when the equity market is in a bearish state, negative oil price shocks impact equity market returns negatively (causing equity markets to fall). Nusair and Al-Khasawneh (2018) conclude that oil and equity market prices are most likely to rally and weaken together and that oil price effects are dependent also on equity market conditions.

Recent studies show that the quantile regression can be extended to a quantile-on-quantile regression to better estimate the asymmetric dependence between oil prices and equity market returns. The quantile-on-quantile regression allows us to evaluate the quantile effects of oil price shock on the quantiles of equity market returns, compared to the simple quantile method which only estimates the effects of oil price shocks on the quantiles of equity market returns. In other words, the quantile-on-quantile approach can explain how different 'states' of oil price shocks impact the equity market under different market circumstances. For instance, with the quantile-on-quantile approach, one can analyse the effect of extreme negative and positive oil price shocks as well as small negative and positive oil price shocks on equity market returns in a bearish state compared to when the market is in a balanced or bullish state.

The quantile-on-quantile approach was first used in this area of research by Sim and Zhou (2015) and has since been applied by several researchers (Tchatoka et al., 2018 and Reboredo and Ugolini, 2016). Sim and Zhou (2015) use the quantile-on-quantile technique to examine the association between US real equity market returns and real oil price shocks. The study employs monthly data from 1973 to 2007 and finds that extreme negative oil price shocks impact equity market returns of US when the equity market is performing well i.e. bullish state. On the other hand, the results show that though large negative oil price shocks could impact US equity market returns, positive oil price shocks have a weak influence on US equity market returns.

Reboredo and Ugolini (2016) analyse the impact of quantile and interquantile oil prices on equity market returns quantiles of three developed economies and the five countries that make up the BRICS bloc. However, their study differs from the current study as they assess the dependence between equity market returns and oil prices instead of oil price shocks. Reboredo and Ugolini

(2016) use weekly data spanning from 2000 to 2014 to assess the dependence structure between oil prices and equity market returns through copulas. The copulas allow them to compute equity market returns that are dependent on large positive or negative oil price shocks. They assess the effect of extreme positive or negative oil price shocks by testing whether the impact on conditional equity market returns differs significantly from the unconditional equity market returns. Their findings suggest that the impact of large negative and positive oil price shocks on lower and upper equity market returns quantiles was small before the financial crisis. Secondly, they find that the effects of large negative oil price shocks were greater than the effects of a large positive oil price shock for all countries before the financial crisis. Lastly, the results show that minor changes in the price of oil, whether positive or negative, did not have a significant impact on equity market returns quantiles before and after the crisis.

Tchatoka et al. (2018) investigate the relationship between oil prices and equity market returns relying on the quantile-on-quantile approach similar to Sim and Zhou (2015). However, Tchatoka et al. (2018) extend their data to cover 15 countries classified into economies that export and import oil as well as their net positions in crude oil trade. Using monthly data from 1988 to 2007, their results suggest that the findings of Sim and Zhou (2015) that extreme negative oil price shocks boost equity market returns when the stock market is performing well is supported by China, India and Japan which are large oil consumers.

The current study differs from studies that employ quantile-on-quantile in assessing the relationship between oil price shocks and equity returns in different aspects. Firstly, the study intends to assess how this relationship differs per countries given their factor endowment (i.e. whether they export or import oil) within the BRICS grouping. Secondly, we also differ from Sim Zhou (2015) and Tchatoka et al. (2018) because we introduce the supply shocks by following the same structure as Kilian and Park (2009) but changing the Cholesky decomposition by ordering real oil price first, assuming the contemporaneous response of global production to oil price. This is supported by the fact that the Organization of the Petroleum Exporting Countries (OPEC) often restricts oil production in response to low oil prices.

3. Methodology

3.1. Identifying oil price shocks

We make use of a SVAR (structural vector autoregression) model to extract the exogenous demand-driven and supply-driven oil price shocks from the global oil market block. We adopt Kilian and Park (2009) who describe this as a block of three variables that are inherent in the movement of oil prices in the global oil market. These variables are global oil production, global real activity in commodity markets and the real price of oil.

To extract demand-driven oil shocks, we order the variables starting with global oil production, followed by the index for global real activity in commodity markets and the real price of oil as the last variable, just as Kilian and Park (2009) did. The order assumes that the supply of crude oil does not respond instantaneously to unexpected changes in demand for oil. Secondly, unexpected changes in the real oil prices that are driven by shocks that are specific to the oil market will not increase or decrease global real economic activity within a month. Lastly, unexpected changes in the real price of oil cannot be explained by sudden changes in oil supply or global aggregate demand for industrial commodities. Furthermore, this study extracts supply-driven oil shocks by ordering the variables starting with the real oil price, followed by global oil production and an index for global real activity in commodity markets, whereby the supply-driven oil shocks are identified from global oil production.

It is worth noting that the structural VAR, expressed as:

$$A_0 z_t = \alpha + \sum_{i=1}^{p} A_i z_{t-1} + A_0 e_t \qquad (1)$$

and a reduced-form VAR expressed as:

$$z_t = \alpha + \sum_{i=1}^{p} z_{t-1} + \varepsilon_t \qquad (2)$$

where z_t is the vector of endogenous variables, e_t is a vector that consists of structural shocks that are serially and mutually uncorrelated.

The vector of reduced-form VAR disturbance terms is denoted by ε_t From (1) and (2), it can be deduced that

$$e_t = A_0{}^{-1}\varepsilon_t \qquad (3)$$

Contemporaneous identification of the structural shocks is imposed through the Choleski decomposition of matrix A_0, triangular structure on $A_0{}^{-1}$. The structure is like that of Kilian and Park (2009). The expression of the triangular structure is provided below, and this shows the association between reduced-form VAR disturbance terms and the structural shocks.

$$e_t = \begin{pmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \end{pmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ a_{21} & 1 & 0 \\ a_{31} & a_{32} & 1 \end{bmatrix}^{-1} \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{pmatrix} \qquad (4)$$

The vector of structural shocks represents structural shocks to the three variables mentioned above. In fact, e_{1t}, e_{2t}, e_{3t} represent structural shocks to global oil production, global real activity in industrial commodity market and real price of oil respectively. According to Kilian and Park (2009), the first identifying restriction is on the assertion that the supply of crude oil will not respond to oil demand shocks contemporaneously due to the costs associated with adjusting production of oil and uncertainty in the oil market.

The second restriction has to do with the sluggishness of global real activity in industrial commodity markets. The assumption is that a rise in the real oil price will not be fully reflected in the movement of global real economic activity contemporaneously. The final identifying restriction identifies e_{3t} as oil price demand shocks. This is due to the fact that the demand for oil price adjusts given the global real activity and the total oil production.

Contrary to past studies that rely only on the demand shocks for oil price, we introduce the supply shocks by following the same structure as Kilian and Park (2009), but by ordering the oil price first, assuming the contemporaneous response of global production to oil price. This is supported by the fact that the Organization of the Petroleum Exporting Countries (OPEC) often restricts oil production in response to low oil prices.

3.2. Quantile-on-quantile approach

As stated earlier, the quantile-on-quantile approach aims to assess how the different quantiles of the regressors affect the dependent variable at different quantiles, while the traditional quantile regression is applied to assess how a specific regressor explains a dependent variable at different quantiles or distribution.

It is important to note that the quantile-on-quantile methodology is based on the combination of quantile regression and non-parametric estimation. To understand how the methodology works, we first express a model for $\theta - quantile$ of equity returns as a function of oil price shocks as:

$$r_t = \beta^{\theta}(oilshock_t) + \alpha^{\theta} r_{t-1} + v_t^{\theta}, \qquad (5)$$

where v_t^{θ} is an error term that has a zero θ-quantile. $\beta^{\theta}(\ )$ is a link function that relates equity returns to oil price shocks at a specific quantile. To analyse the relationship between θ-quantile of equity returns and the ω-quantile of oil price shocks, $oilshock^{\omega}$, equation (5) is examined in the neighbourhood of oil^{ω} by linearising $\beta^{\theta}(oil\ )$ in Equation (5) using a Taylor expansion such as:

$$\beta^{\theta}(oilshock_t) \approx \beta^{\theta}(oilshock_t^{w}) + \beta^{\theta\prime}(oilshock_t^{w})(oilshock_t - oilshock_t^{w}), \qquad (6)$$

if we rewrite $\beta^{\theta}(oilshock_t^{w})$ as $\beta_0(\theta, w\ )$, stating that the coefficient relates θ-quantile with ω-quantile, Equation (6) will be re-expressed as

$$\beta^{\theta}(oilshock_t) = \beta_0(\theta, w\ ) + \beta_1(\theta, w\ )(oilshock_t - oilshock^{w}) +, \qquad (7)$$

replacing Equation (7) in Equation (5), we will have:

$$r_t = \beta_0(\theta, w\ ) + \beta_1(\theta, w\ )(oilshock_t - oilshock^{w}) + \alpha(\theta) r_{t-1} + v_t^{\theta}, (8)$$

Equation (8) is estimated by solving a non-parametric model based on the following minimisation problem:

$$\min_{b_0, b_1} \sum_{i=1}^{n} \rho_0 \left[r_t - b_0 - b_1\left(\widehat{oilshock}_t - \widehat{oilshock}^{w}\right)\right] K\left(\frac{F_n\left(\widehat{oilshock}_t\right) - w}{h}\right), (9)$$

where a Gaussian kernel $K\left(\frac{F_n\left(\widehat{oilshock}_t\right) - w}{h}\right)$ is used to weight the observation around $oilshock^{w}$

4. Data, estimation and discussion of results

4.1 Data description

The study employs monthly data spanning from January 1998 to December 2017. In this paper, we use the following BRICS equity market prices: Johannesburg Stock Exchange All Share Index, Moscow Exchange Index, India SENSEX Stock Market Index, Shanghai Composite Index and Ibovespa Brasil Sao Paulo Stock Exchange Index. These stock market indices are the largest in their regions and are internationally recognised by investors and portfolio managers as well as other traders in the stock market, especially those seeking to invest and diversify their portfolios by investing in emerging markets. The data for stock prices and West Texas Intermediate (WTI) is obtained from Thomson Reuters. Important to note is that the choice of the price index does not matter because they all exhibit a similar trend and the price difference is not as significant. Furthermore, the oil price data is converted from nominal to real value using the Consumer Price Index (CPI) obtained from the Federal Reserve Economic data. We use US CPI because the oil price index is denominated in US dollars.

The index used for measuring global economic activity is from Professor Kilian's personal website. This index has been updated following criticism by Hamilton (2019) stating that the index hinge on normalization that has substantive consequences. According to Hamilton (2019), the index is susceptible to the choice of base period when estimating the nominal freight index. However, Kilian (2019), states that the concerns raised by Hamilton (2019) are a result of a coding error where the nominal freight rate was unintentionally logged twice. According to Kilian (2019), correcting the error by removing one of the log transformations invalidates concerns raised by Hamilton (2019) and the index can be used as initially intended. The index considers an index linked to a panel of cargo ocean shipping freight rates and reflects the aggregate global demand for industrial commodities such as oil. Moreover, the attractiveness of the index rests on the idea that it takes into consideration the effects of increased real activity in emerging markets such as India and China.

Demand and supply oil shocks are obtained from the SVAR identified with contemporaneous restrictions, as explained in chapter 4 above. We use quantile-on-quantile regression to assess the effect of real oil price shocks on stock market returns in BRICS countries.

Table 1

Descriptive statistics

	ODS	IBOVESPA	JSE	MOEX	SENEX	SHANGHAI	OSS
Mean	0	-0.000492	0.005043	0.003690	0.004661	0.002440	0
Median	0.373689	0.004802	0.007756	0.012781	0.006257	0.006060	0.000349
Maximum	15.28447	0.340268	0.131317	0.370351	0.242207	0.291163	0.059690
Minimum	-25.65094	-0.509929	-0.362311	-0.618611	-0.286598	-0.279779	-0.058266
Standard deviation	5.517616	0.119923	0.055827	0.108853	0.069827	0.079012	0.010716
Skewness	-0.582280	-0.732766	-1.305566	-1.136506	-0.477188	-0.313873	-0.145251
Kurtosis	5.028586	5.009852	10.17409	9.372792	4.287396	4.952967	10.25351

Notes: ODS and OSS stand for oil demand shocks and oil supply shocks respecrtively.

Table 1 presents the descriptive statistics of the variables used in the current study. Firstly, the table shows that South Africa has the highest mean return (0.005043) in the grouping, followed by India, Russia, China and Brazil with mean returns of 0.0046, 0.0037, 0.0024 and -0.0004 respectively. Combined, BRICS countries offer a monthly mean return of 0.015342 which translates to 18.41% per year. Secondly, the values for the skewness are all negative, implying that the data of all the variables is skewed to the left. Thirdly, the values of the kurtosis are positive, indicating a heavy tailed distribution.

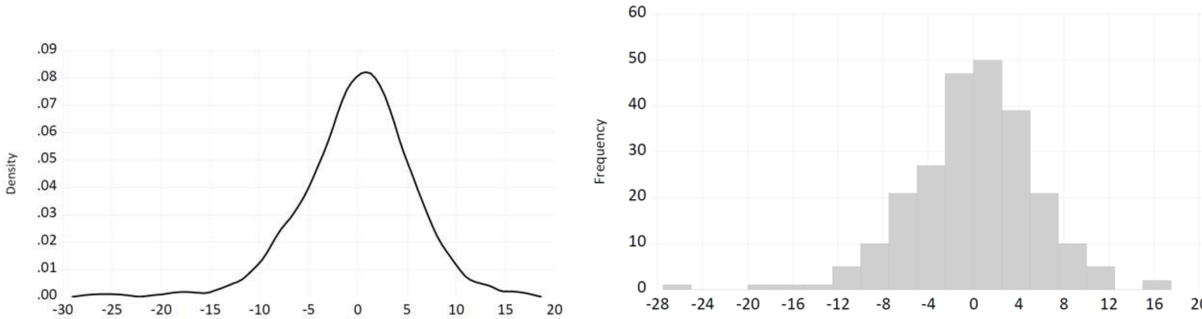


Fig. 1. Distribution of oil-specific demand shocks.

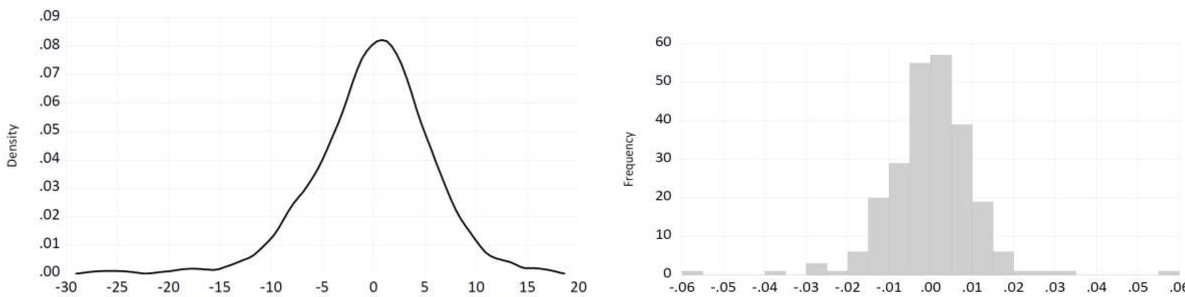


Fig. 2. Distribution of oil-specific supply shocks.

Figure 1 and 2 above show the distribution of oil price shocks. The figures suggest that oil price shocks are not normally distributed and that they are skewed to the left. Furthermore, the results show that most of the data points lie to the negative side of the tail. This means there are more negative oil price shocks than positive ones.

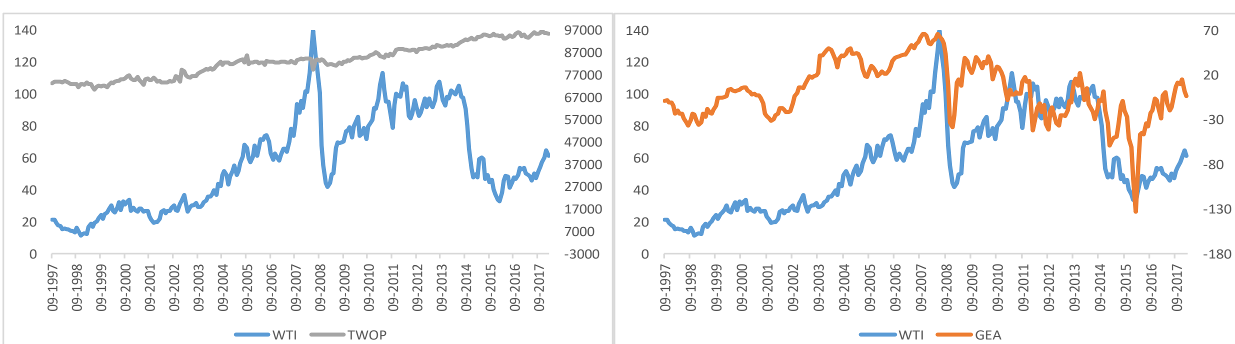


Fig. 3. Graphical presentation of Global Economic Activity Index and total world oil production against West Texas Intermediate.

Figure 3 (left panel) graphs the West Texas Intermediate (WTI) against total world oil production (TWOP) and the right panel graphs WTI oil prices against Global Economic Activity (GEA) Index. The figures show that TWOP has been on an upward trend and show no correlation with the WTI oil prices (left panel). This may indicate that oil supply has been independent to the price of oil, at least during the 1997 to 2017 period. On the other hand, Figure 3 (right panel) shows that GEA — which is a proxy for global demand for commodities — is more correlated with oil prices, suggesting that demand is more important in explaining fluctuations in oil prices. This reality indicates a possible link between demand for oil (commodity) and oil prices. It is certainly in this perspective that Kilian (2009) and Kilian and Park (2009) find that oil price changes caused by shocks specific to demand for oil have a significant impact on the US equity market. However, the response of US equity market returns oil supply shocks is usually weak. Based on this reality, one could postulate that oil demand shocks cause variability in oil prices, while oil supply shocks are not necessary accompanied by observed changes in oil prices and thus, have a minor effect on equity markets.

4.2 Results

4.2.1 Quantile regression plot estimates

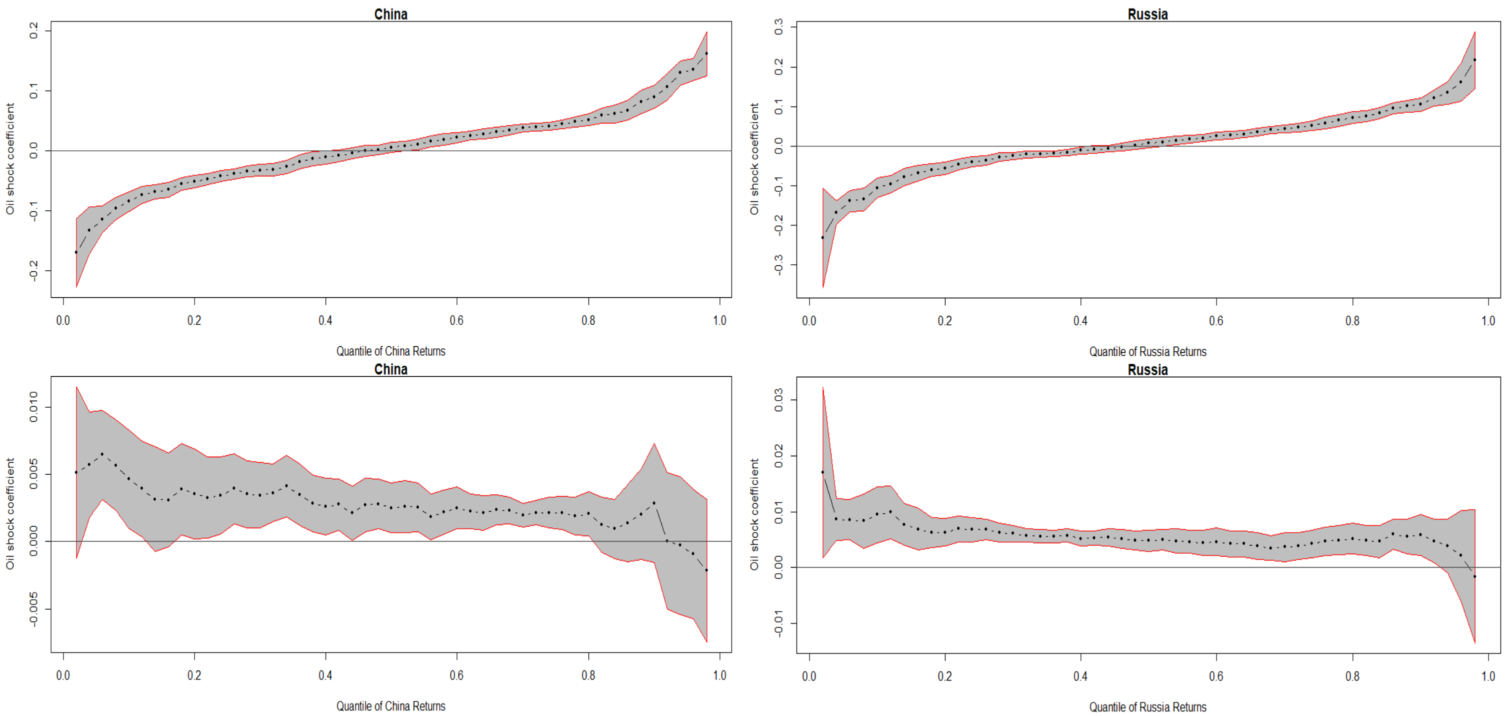


Fig. 4. Plots of the intercept and slope coefficient estimates of a quantile regression for demand driven oil price shock for China and Russia

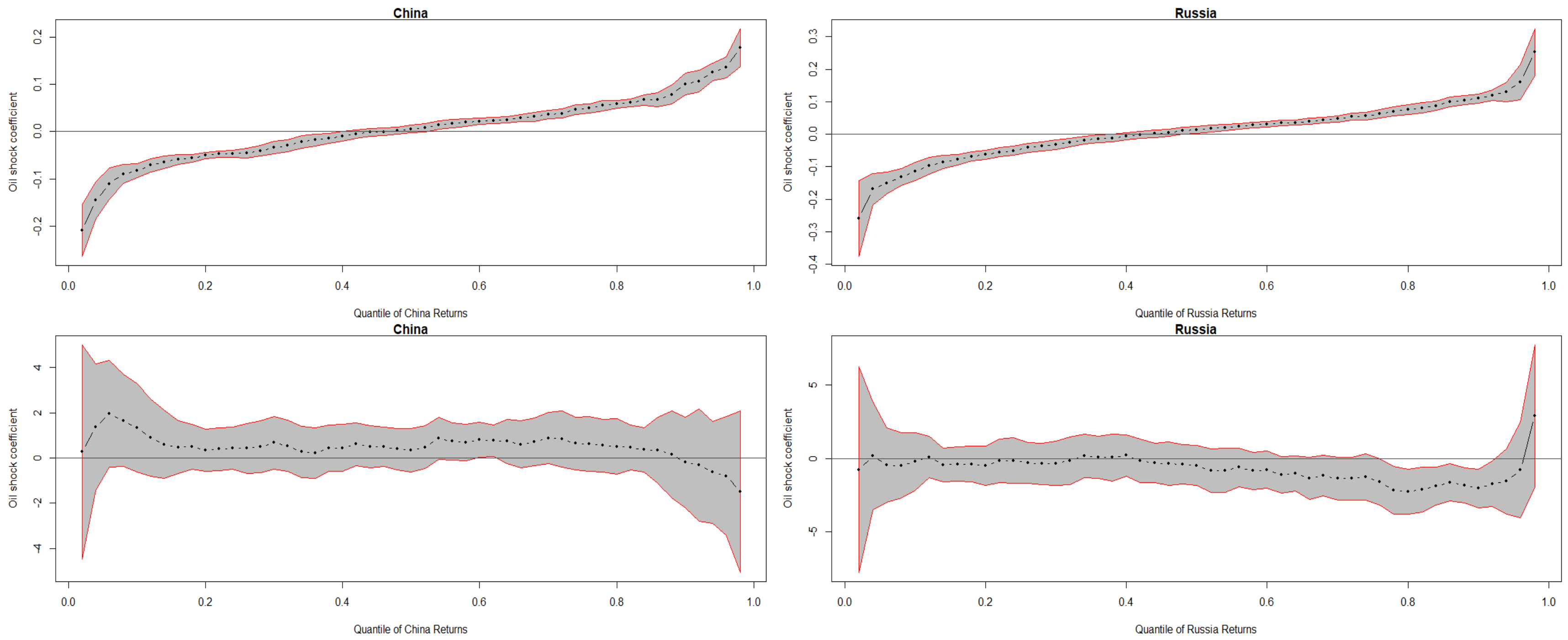


Fig. 5. Plots of the intercept and slope coefficient estimates of a quantile regression for supply-driven oil price shocks for China and Russia

Figure 4 and 5 present the plots of the intercept term (α^{θ}) and slope coefficients of a quantile regression (β^{θ}) given as:

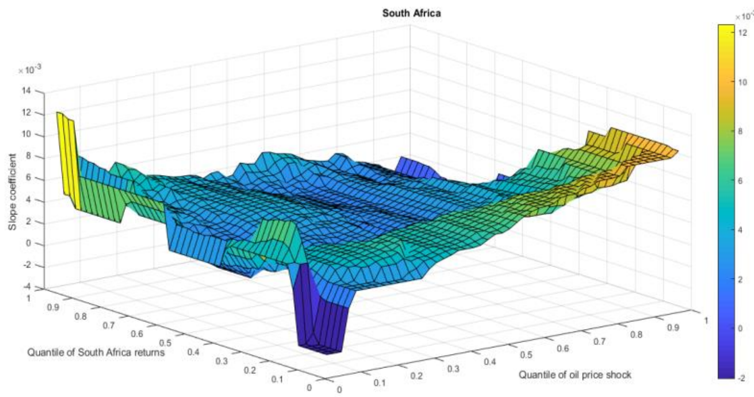
$$r_t = \alpha^{\theta} + \beta^{\theta}(oilshock_t) + \varepsilon_t \quad (10)$$

For simplicity we only show results for one oil-producing country, Russia, and one oil-importing country, China. The other plots are provided in the appendix as well as the results of Equation (10). The plots provide a simple quantile regression representation of the link between oil price shocks and equity market returns. Each figure has two plots, the one on top shows the intercept term plots and the bottom one shows the plots of the slope coefficients. The y-axis represents the slope coefficients and the x-axis represent the quantile of returns. The solid red line which borders the gray shade represents the confidence level at the 90th percentile and the black dots represents the sequences of the quantile regression. In all the figures, we see that the plots of the intercept term are increasing in θ-quantile, implying that the intercept is small for lower quantiles and larger for upper quantiles, reflecting the increase in equity returns at the right tail of the distribution.

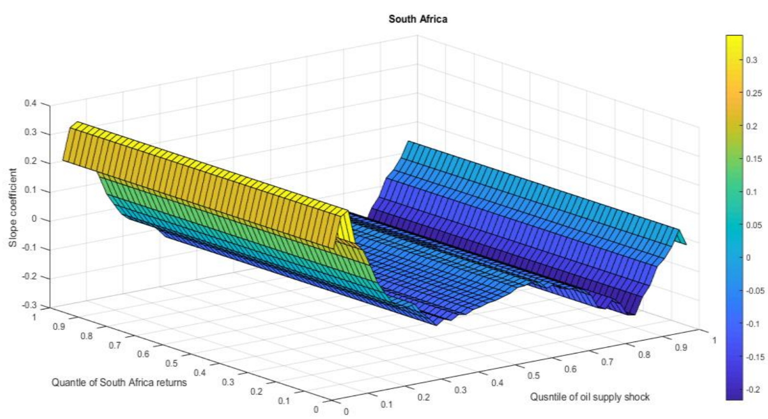
On the other hand, we notice that the plots of the slope coefficients have more variations at the tails of the distribution, depending on whether the country is an oil producer or not. For example, a high demand shock (right tail of the distribution) reduces equity returns of non-oil-producing countries (China in this case). Such a decrease occurs with negative demand shocks in oil-producing countries (Russia). Based on these findings from the quantile regression, we could expect to find pronounced evidence of coefficient variation from the quantile-on-quantile regression, depending on the resource (oil) endowment of each BRICS country.

4.2.2 Quantile-on-quantile results

South Africa



(a) 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific demand shocks (w)



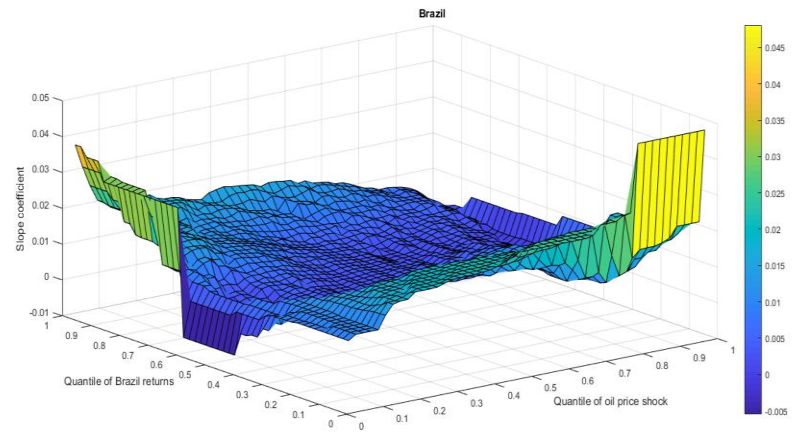
(b) 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific supply shocks (w)

Fig. 6. 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific shocks (w) for South Africa.

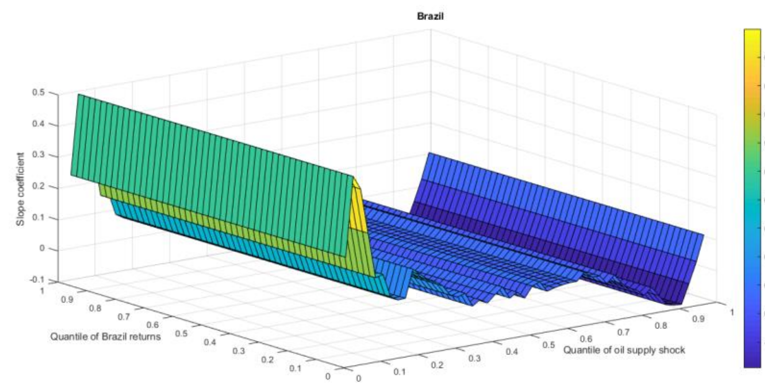
Figure 6 plots the slope coefficients of $\hat{\beta}_1(\theta, w)$, as obtained from the estimation of Equation 4. The results displayed in Figure 6 (a) show the effects of the different quantiles of demand oil-price shocks on the different quantiles of equity market returns in South Africa. For instance, at a lower quantile of the demand oil-price shocks, which may correspond to negative demand for oil and the drop of its price thereof, the equity market of a net importing crude oil country such as South Africa performs well by reaching a peak of close to 1.2% monthly returns under better equity market conditions (higher quantile of equity market returns). However, during bad equity market condition (lower quantile), the negative demand for oil fails to enhance the performance of equity markets. This indicates that lower oil prices may be the necessary, but not the sufficient, condition to boost equity markets during market turmoil. Figure 6(a) shows that high demand price shocks depress the performance of the equity market in South Africa when the latter is in a boom phase. This may be due the spill-over effects of high oil prices. However, the results displayed in Figure 6(a) show that high oil prices may enhance the South African equity market during tumultuous periods. The plausible explanation may be due to the fact that South Africa is a commodity-producing country, and high demand for oil that is triggered by global commodity demand may be beneficial for the South African equity market, especially during a period of turmoil.

Contrary to $\hat{\beta}_1(\theta, w)$ in Figure 6 (a), $\hat{\beta}_1(\theta, w)$ in figure 6 (b), which shows the 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of equity market conditions (θ) and the magnitude of oil-specific supply shocks (w) $\hat{\beta}_1(\theta, w)$, show that the effect of the supply shocks is independent of equity market conditions. For example, Figure 6(b) demonstrate that small oil supply shocks improve equity market returns in South Africa regardless of equity market conditions. However, big oil supply shocks are detrimental to equity market in South Africa — independent of market conditions. The rationale of these findings may be that given the poor correlation between oil supply shocks and oil prices, big supply shocks may reflect high excess supply due to insufficient demand. Such a huge gap between supply and demand of oil occurs during economic and financial crises. Thus, it is evident that during crisis periods, equity markets are affected negatively, independent of the state the market is in.

Brazil



(a) 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific demand shocks (w)

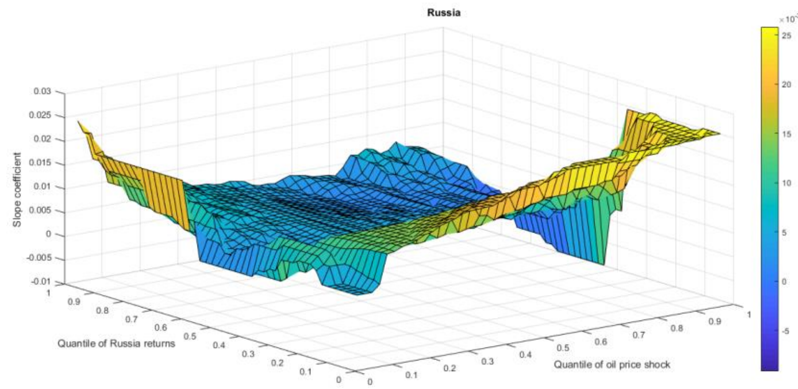


(b) 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific supply shocks (w)

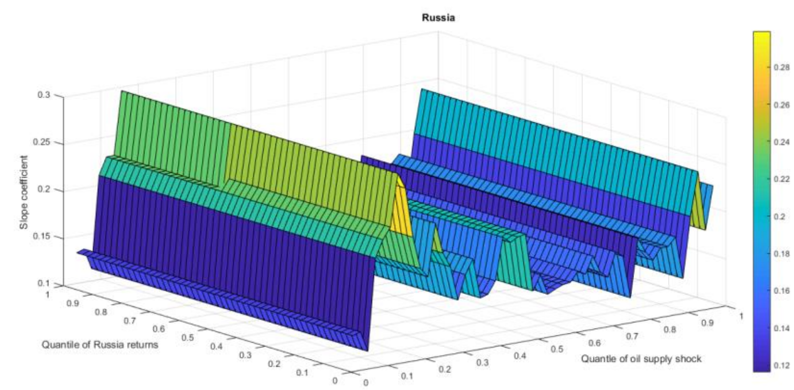
Fig. 7. 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific supply/demand shocks (w) for Brazil

Figure 7 (a and b) plots the slope coefficients of $\hat{\beta}_1(\theta, w)$ for the demand and supply oil shocks respectively. The displays of Figures 7a and 7b are similar to Figures 6a and 6b, the case of South Africa. This is evident given that Brazil is a commodity-producing country just like South Africa. Although Brazil is the second-largest crude oil producer in Latin America, after Venezuela, the country continues to import oil due to high domestic demand for oil and the low grade of crude oil produced in Brazil. This reality makes Brazil to be a net importer of oil on average. Nonetheless, as a producer of oil, Figure 7(a) shows that a high demand shock, translated through high oil prices, provides an incentive for the local stock market to surge during periods of turmoil.

Russia



(a) 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific demand shocks (w)

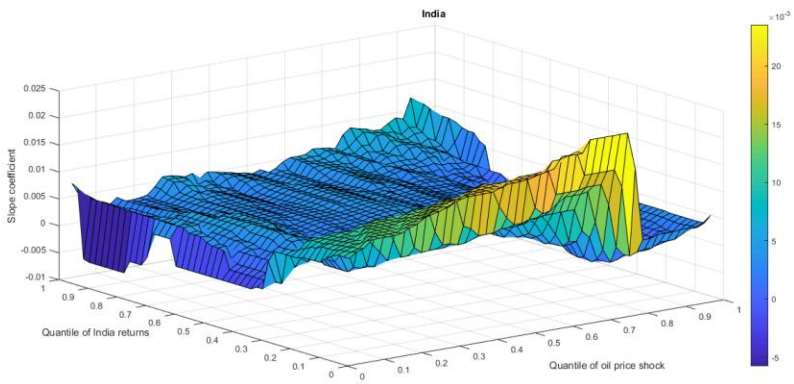


(b) 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific supply shocks (w)

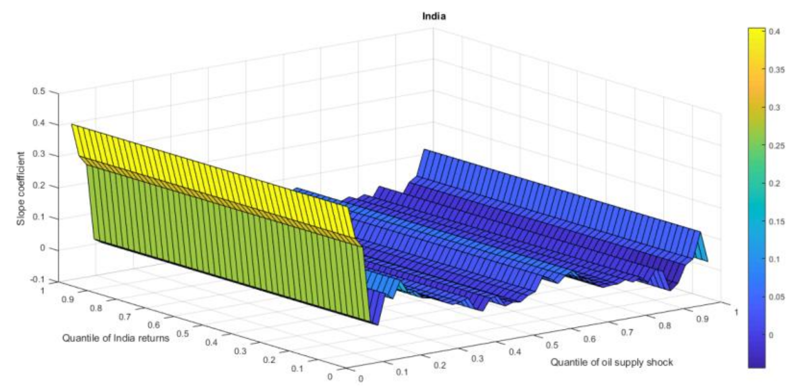
Fig. 8. 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific supply/demand shocks (w) for Russia.

Figure 8 (a and b) plots the slope coefficients of $\beta_1(\theta, w)$, explaining the correlation between the quantile of the equity market and the quantile of demand and supply oils-price shocks, respectively, for Russia. With Russia being a net oil exporter and an important oil-producer in the BRICS grouping and the second-largest producer in the world, the correlation between equity market returns and oil-price shocks in the country is different to other members of BRICS. In fact, Figure 8a shows that a high demand oil shocks, which translate to a rise in oil prices, constitute an incentive for the boost of equity market, especially when the equity market is at a lower phase of its financial cycle. Thus, high oil demand shocks trigger an expansionary phase in the Russian equity market. With regards to oil-supply shocks, Figure 8b shows that supply shocks have a moderate effect on Russia's equity market. At a lower quantile of supply shocks, the effects are relatively better than the higher quantile given the negative effect the excess supply of oil has on an oil-producing country.

India



(a) 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific demand shocks (w)



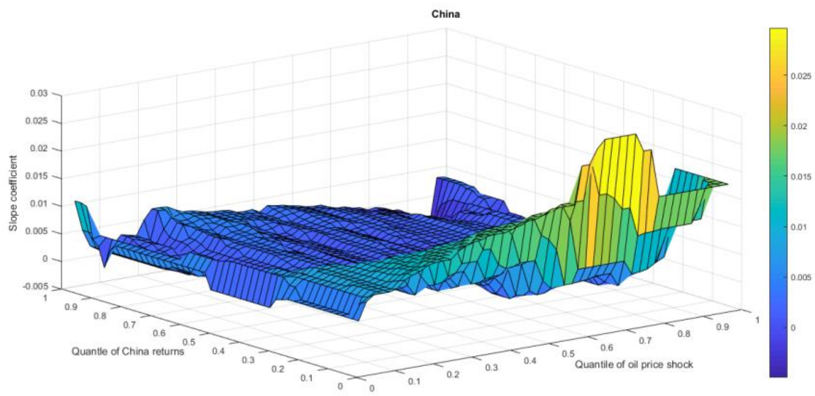
(b) 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific supply shocks (w)

Fig. 9. 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific supply/demand shocks (w) for India.

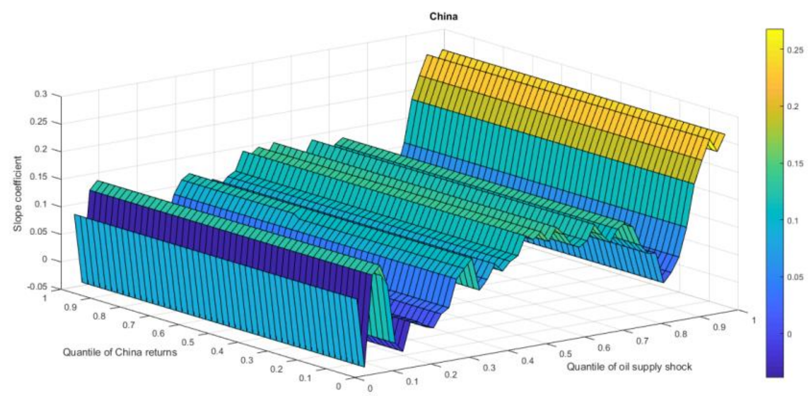
Figure 9 (a and b) plots the slope coefficients of $\hat{\beta}_1(\theta, w)$ for the case of India. Although India has an estimated crude oil reserve evaluated at 595 million tonnes, the country imports 82% of its oil need (BP Statistical Review, 2019). Thus, the country is a net importer of oil, the third top net crude oil-importer after the US and China. This duality of being an exporter and importer of oil impacted the outcome of the link between the state of the equity market and the quantile of the demand and supply oil shocks. Figure 9(a) shows that the increase in oil demand shocks is an incentive for the expansionary phase of the financial cycle in India's equity market. Moreover, an increase in supply shocks at a lower quantile contributes positively to the Indian equity market.

However, excess supply, related to economic and financial crises, reduces the returns of the equity market in India. This is mostly due to the vulnerability of India to financial contagion.

China



(a) 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific demand shocks (w)



(b) 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific supply shocks (w)

Fig. 10. 3D representation of $\hat{\beta}_1(\theta, w)$ as a function of market circumstances (θ) and oil-specific supply/demand shocks (w) for China.

Figure 10 (a and b) plots the slope coefficients of $\hat{\beta}_1(\theta, w)$ for the case of China. Although China is the world's fourth-largest producer of oil, the country is a net oil importer, with the internal demand for oil exceeding domestic production since 1993 as the country needed to ensure adequate energy supply to sustain its economic growth (King, 2005). While the effects of the demand oil-price shocks on equity returns in China are similar to other net oil-importing countries in the BRICS group, the outcome of the supply shocks on equity returns in china is different. In fact, it is shown in Figure 10(b) that during the period of excess supply of oil, China's equity market thrives the most. The rationale of this outcome is supported by the fact that the excess supply provides enough incentive for China to sustain its domestic production. Moreover, given that China has been insulated for financial contagion during periods of global crises, especially the 2008 global financial crisis, it is evident that its equity market becomes a safe haven during such times. Studies show that China has been able to successfully boost domestic demand to reduce the negative effects of the global recession (Wise, Armijo and Katada, 2015).

Overall, the results discussed above on the correlation between oil-price shocks and the performance of equity returns show that the asymmetry of this relationship may be further understood by distinguishing between the state of the equity market of the distribution of oil-price shocks. In addition, distinction should be made between demand-driven and supply-driven oil price shocks and that the outcome of this relationship depends on whether a country is a net crude oil exporter or importer. For most of countries that are net oil-importers, the low oil price demand shocks, which translate to lower oil prices, further stimulate equity markets when they are at peak. And for oil-producing countries in general, high demand oil price shocks provide an incentive for the expansion of equity markets during bad market conditions. Furthermore, the results show that higher oil prices provide an incentive for BRICS stock markets to surge during periods of turmoil. Another similarity is that higher demand shocks have negligible impact on BRICS equity market returns when the market conditions are good.

5. CHARPTER SIX: CONCLUSION

This study assesses the effects of oil price shocks on equity market returns in the BRICS bloc, using a quantile-on-quantile regression to show that this relationship is dependent upon equity market conditions and the distribution of oil price shocks — distinguishing the demand-driven and supply-driven oil price shocks. The study extends the contribution of Sim and Zhou (2015) by distinguishing between the demand and supply driven oil price shocks when applying quantile-on-quantile regression. The methodology is applied to BRICS grouping to differentiate the effects of oil price shocks and equity market returns between countries that are net-exporters and importers. In attempting to assess the link between equity market conditions and the distribution of oil price shocks, the study is able to assess what would happen to the performance of equity markets when it is in the lower phase of a financial cycle (trough or turmoil periods) and if there is low or high demand, or supply-driven oil price shocks.

The results confirm that the effect of oil price shocks on equity market returns in BRICS countries vary depending on the state of equity market and the magnitude of oil price shock. For example, the results of the empirical analysis show that high demand oil price shocks provide an incentive for the expansion of equity markets during bad market conditions, mostly in countries that are oil exporters. Overall, the results of the empirical analysis show that the relationship between oil price shocks and the performance of equity markets depict an asymmetry behaviour, depending on the condition of the equity market (i.e. bearish, balanced or bullish) and the distribution of oil price shocks.

Moreover, the results of the empirical analysis show that distinction should be made between the demand-driven and supply-driven oil price shocks and that the outcome of this relationship depends on whether a country is a net importer or exporter of crude oil. For most of the net oil-importing countries, the low oil price demand shocks, which translate to lower oil prices, further stimulate equity markets when they are at peak. And for oil-producing countries in general, high demand oil price shocks provide an incentive for the expansion of equity markets during bad market conditions.

APPENDIX

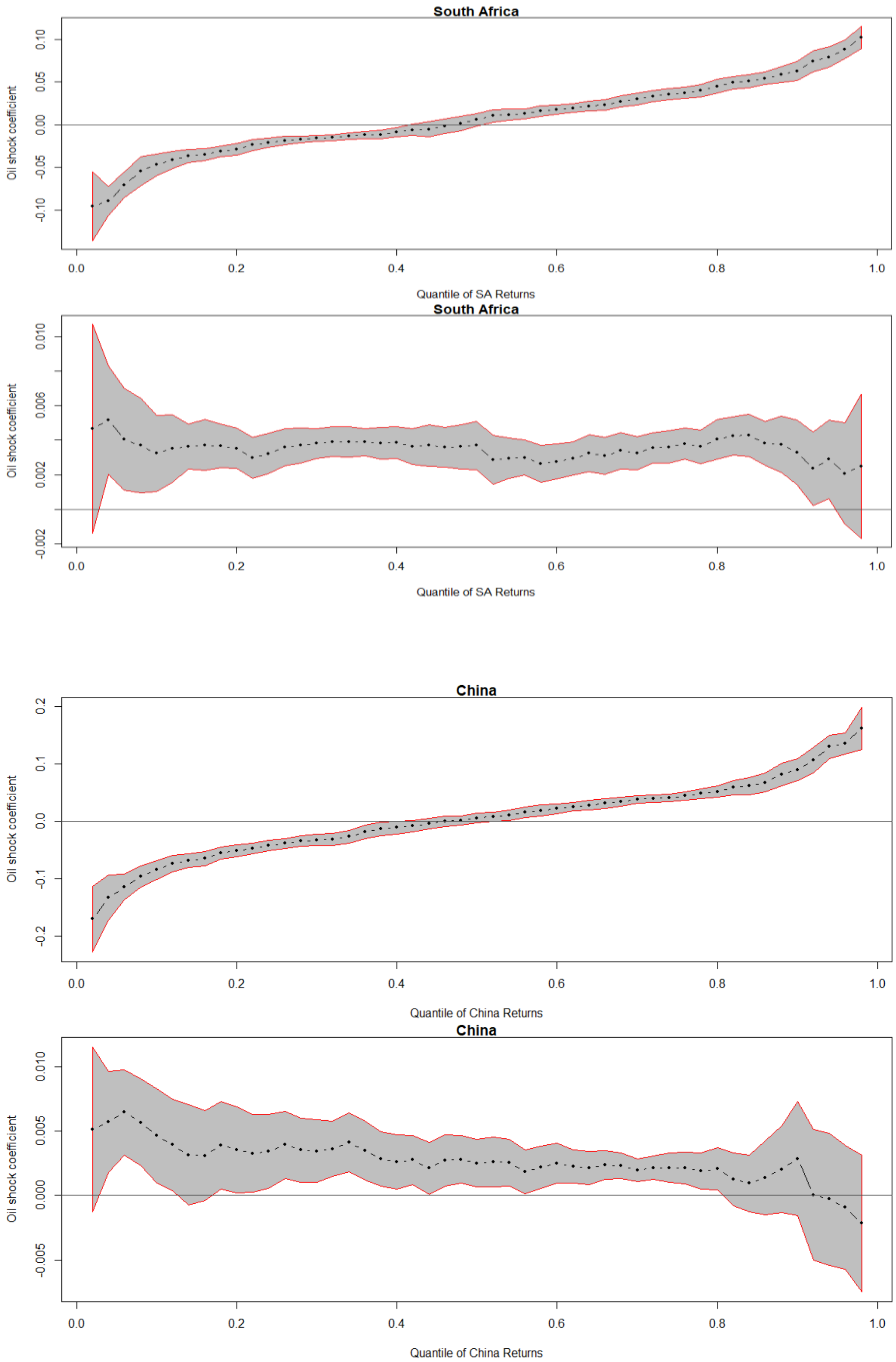
Table A1: Coefficients of the link function $\beta^{\theta}(\,)$ that relates equity returns to oil-specific demand shocks at a specific quantile

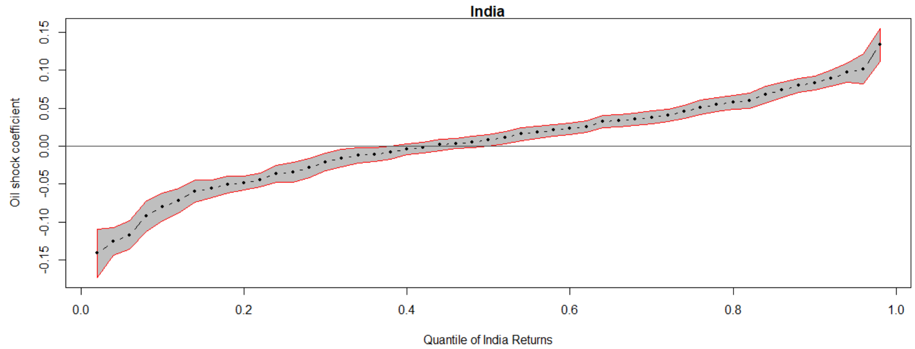
		Coefficients				
Market Conditions	Tau	Brazil	Russia	India	China	South Africa
Positive	80th	0.00685***	0.00466***	0.00299**	0.00164	0.00394***
	90th	0.00334	0.00406*	0.00264**	0.00158	0.00375***
Balanced	50th	0.00546***	0.00487***	0.00416***	0.00416***	0.00285***
Negative	10th	0.00962***	0.00788***	0.00549***	0.00549***	0.00294**
	20th	0.01144***	0.00709***	0.00491***	0.00491***	0.00353***

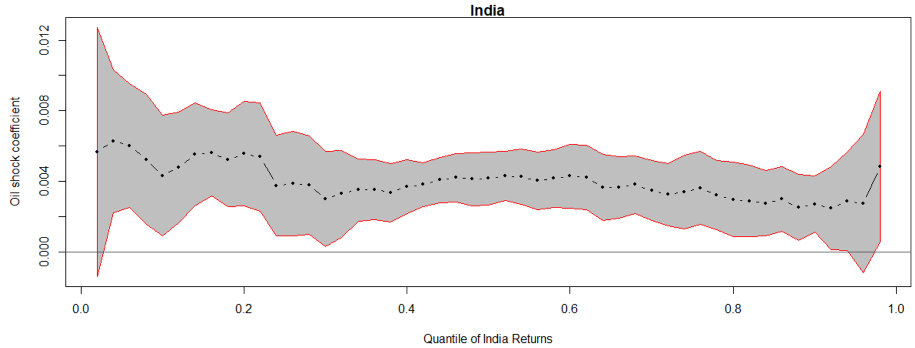
Table A2: Coefficients of the link function $\beta^{\theta}(\,)$ that relates equity returns to oil-specific supply shocks at a specific quantile

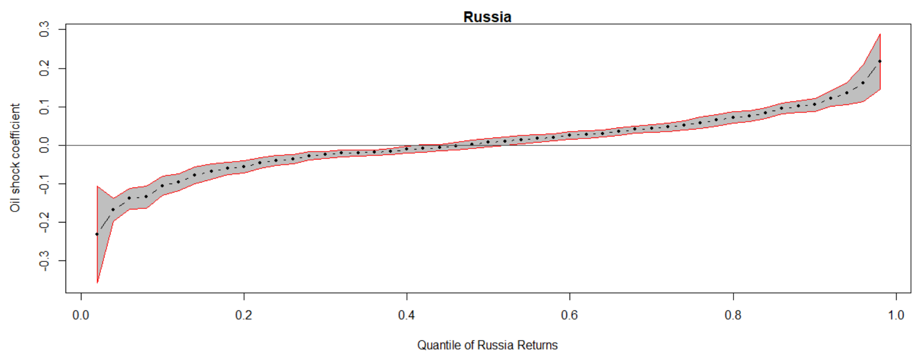
		Coefficients				
Market Conditions	Tau	Brazil	Russia	India	China	South Africa
Positive	80th	0.51537	-1.92753*	-0.43155	0.62844	-0.32774
	90th	0.28127	-1.55495*	0.07772	-0.03612	-0.16831
Balanced	50th	-0.84906	-0.48540	-0.60835	1.18823**	-0.78918
Negative	10th	-0.43149	0.38677	0.07099	1.33770	0.01448
	20th	-0.43108	-0.28671	0.89978	0.35786	-0.13493

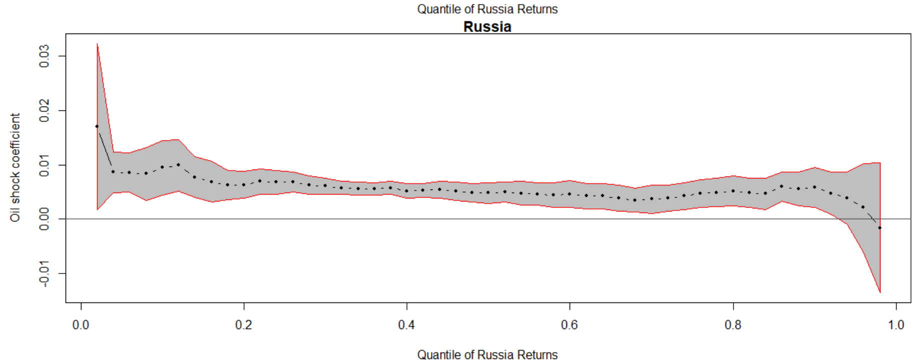
Figure A1: Plots of the intercept and slope coefficient estimates of the quantile regression for oil demand shocks.




India
Oil shock coefficient
-0.15 -0.10 -0.05 0.00 0.05 0.10 0.15
0.0 0.2 0.4 0.6 0.8 1.0
Quantile of India Returns


India
Oil shock coefficient
0.000 0.004 0.008 0.012
0.0 0.2 0.4 0.6 0.8 1.0
Quantile of India Returns


Russia
Oil shock coefficient
-0.3 -0.2 -0.1 0.0 0.1 0.2 0.3
0.0 0.2 0.4 0.6 0.8 1.0
Quantile of Russia Returns


Russia
Oil shock coefficient
-0.01 0.00 0.01 0.02 0.03
0.0 0.2 0.4 0.6 0.8 1.0
Quantile of Russia Returns

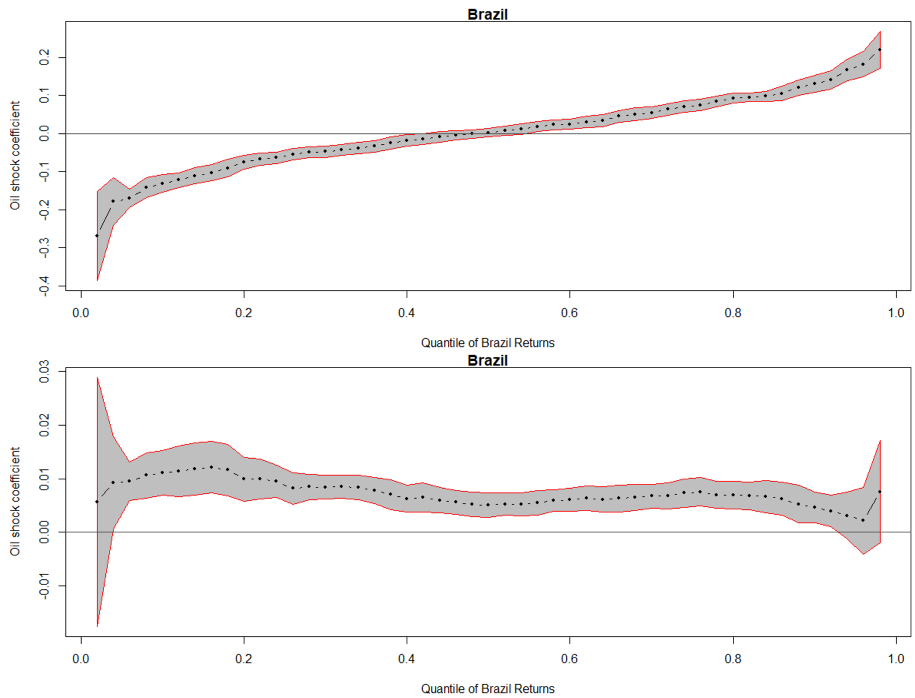
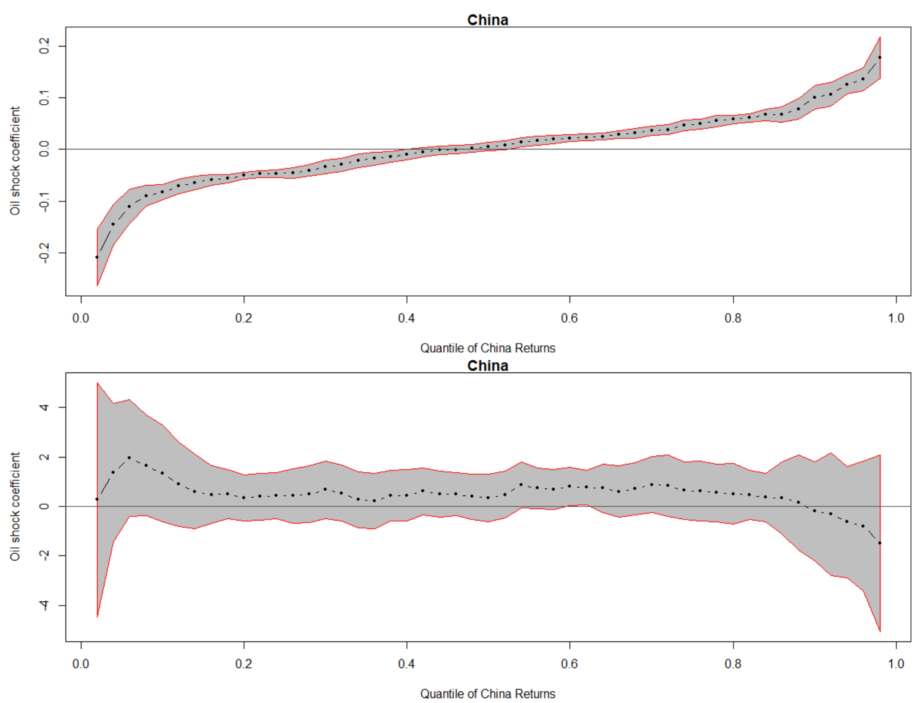
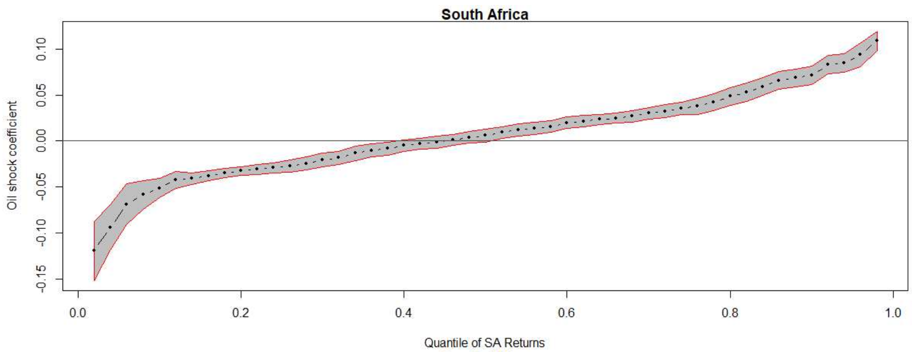
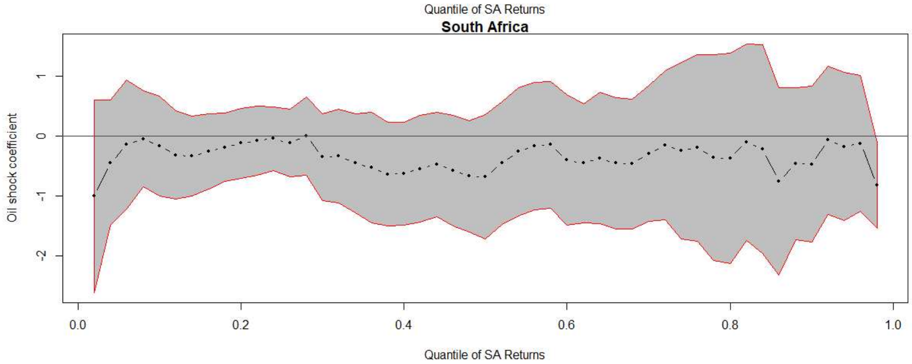
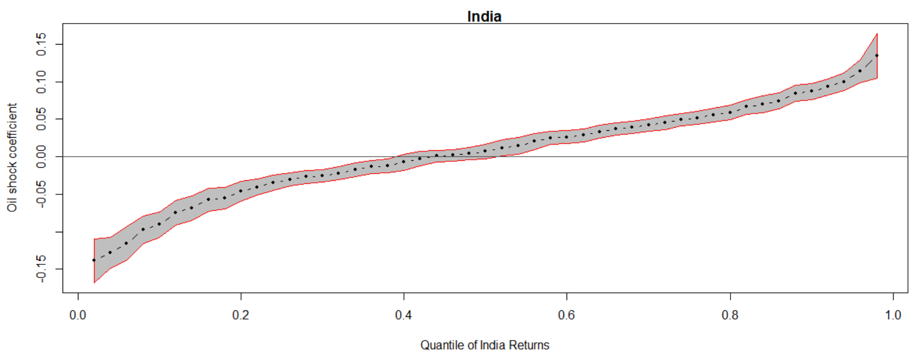


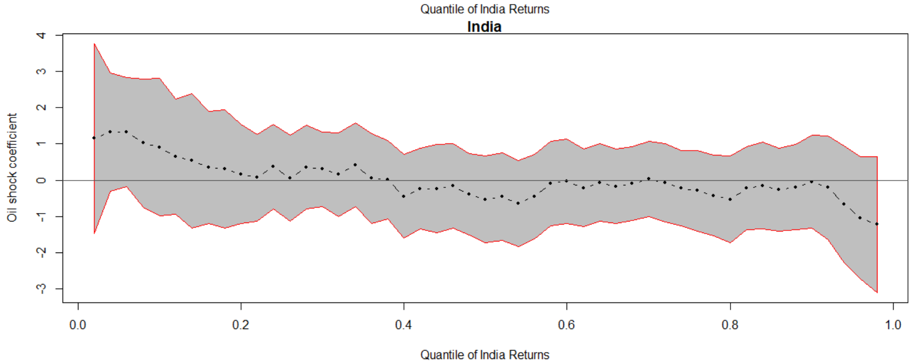
Figure A2: Plots of the intercept and slope coefficient estimates of the quantile regression oil supply shocks.

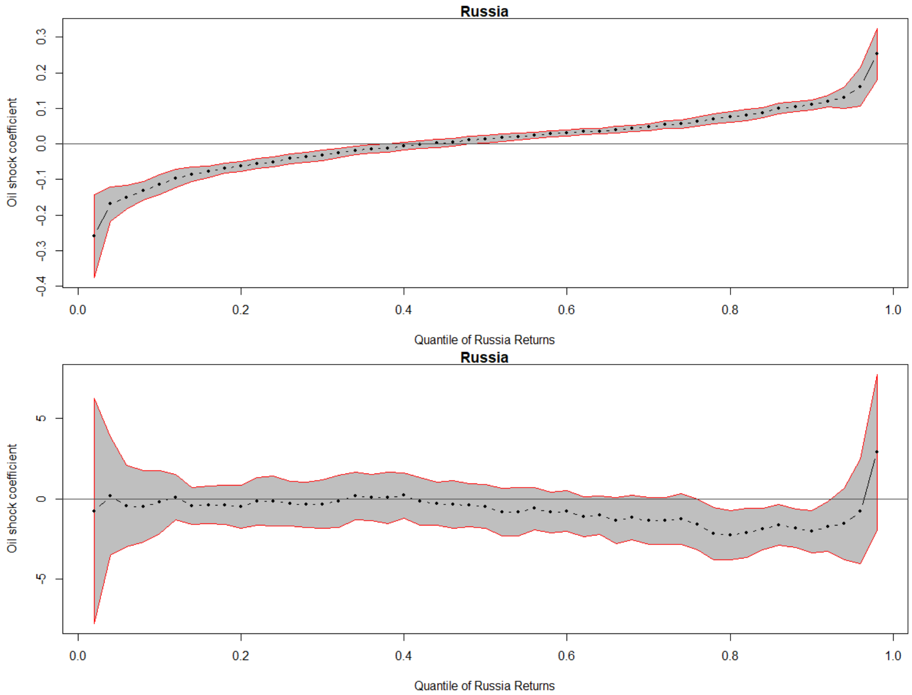



South Africa
Oil shock coefficient
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.0
0.2
0.4
0.6
0.8
1.0
Quantile of SA Returns

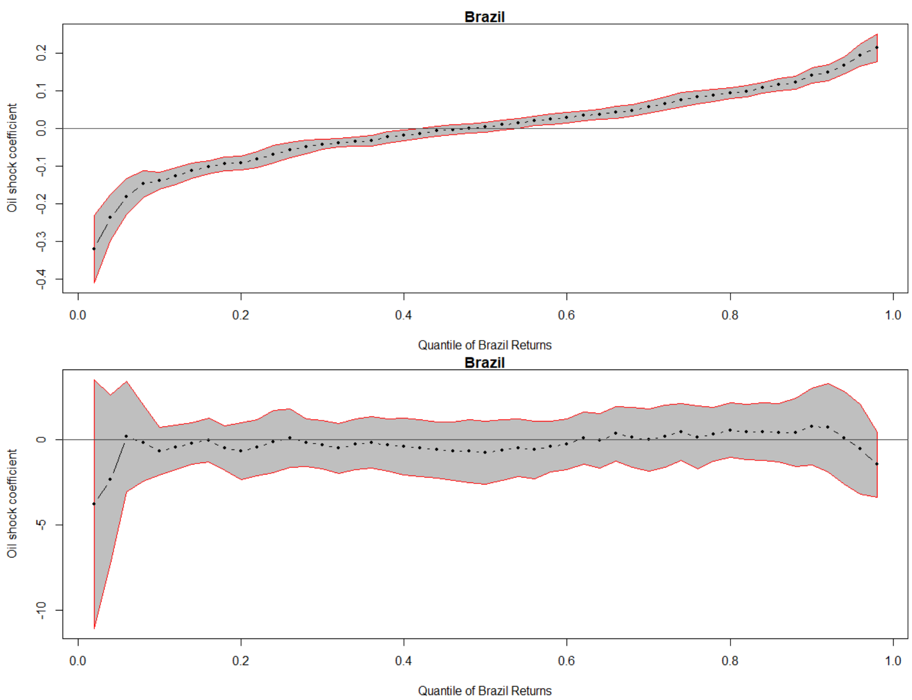

South Africa
Oil shock coefficient
-2
-1
0
1
0.0
0.2
0.4
0.6
0.8
1.0
Quantile of SA Returns


India
Oil shock coefficient
-0.15
-0.05
0.00
0.05
0.10
0.15
0.0
0.2
0.4
0.6
0.8
1.0
Quantile of India Returns


India
Oil shock coefficient
-3
-2
-1
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0
Quantile of India Returns



Russia
Oil shock coefficient
Quantile of Russia Returns
Russia
Oil shock coefficient
Quantile of Russia Returns



Brazil
Oil shock coefficient
Quantile of Brazil Returns
Brazil
Oil shock coefficient
Quantile of Brazil Returns

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