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The Effects of Energy Prices on Oil-Gas Sectoral Stock Returns for BRIC Countries: Evidence from Space State Models

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ABSTRACT

This paper examines the effects of oil and natural gas prices on the oil and gas sectors of the BRIC countries (Brazil, Russia, India, and China) over the period over from 2013 to 2022. Unlike previous studies, it employs a time-varying capital asset pricing model based on the estimation of state-space mode. In brief, the findings highlight significant changes in the asset-pricing model parameters across all countries, indicating the limitations of using time-invariant estimates. Specifically, Brazil shows the highest volatility in oil price risk, followed by Russia, both being oil-exporting countries, while market beta values remain relatively stable. Time-varying estimates further suggest that natural gas parameters are relatively lower and less significant than those of oil prices. The Russian-Ukrainian conflict's energy crisis adversely affects the performance of oil and gas sectoral stock returns. This war has had a negative and significant impact on China's oil-gas stock return.

Keywords: Oil Prices, Natural Gas Prices, Oil-gas Sectoral Returns, Time-varying Parameter Model, BRIC Countries
JEL Classifications: C5, C58, G12.

1. INTRODUCTION

Crude oil is an essential raw natural resource for the development of countries since it is a primary source of energy and raw material for petroleum products. It remains the primary source of energy, accounting for 30.83-30.9 percent of the global energy consumption in 2020 and 2021, besides natural gas, nuclear energy, hydroelectricity, renewable sources of energy, and coal (BP, 2022).[1] Historically, investors have placed their funds in financial asset markets in addition to oil markets (Arouri and Nguyen, 2010). According to Umar et al. (2021), stock prices can be affected by several factors, including volatility, inflation, sovereign risk, and oil prices. Despite the general consensus regarding the importance of oil prices in the global economy, there is no consensus regarding the impact of stock market fluctuations on the oil market. Numerous empirical studies have followed the seminal studies of Huang et al. (1996) and Jones and Kaul (1996), but it is difficult to determine the impact of changes in oil prices (Hammoudeh and Choi, 2006; Park and Ratti, 2008; Apergis and Miller, 2009). Moreover, fluctuations in oil prices may affect national economies differently depending on whether the country exports or imports oil. Oil prices and stock prices have mixed findings both in terms of the strength of their relationship and its significance (Huang et al., 1996; Hammoudeh and Choi, 2006; Park and Ratti, 2008; Apergis and Miller, 2009), as well as in terms of its importance over time (Miller and Rati, 2009; Lee and Zeng, 2011) or across economies (Jones and Kaul, 1996; Nandha and Hammoudeh, 2007; Mohanty et al., 2011; Arouri and Rault,

1 In terms of energy consumption, coal is the second most common resource, followed by natural gas. By 2020, coal will contribute 26% of the energy consumed, while natural gas will contribute 24%.

2011; Akoum et al., 2012; Wang et al., 2013). Additionally, oil shocks have been described in terms of their nature (Kilian and Park, 2009; Kang et al., 2016; Basher et al., 2018).

According to Park and Ratti (2008), oil price shocks positively affect the stock returns of oil-exporting countries, such as Norway, regardless of their oil export status. Furthermore, Filis and Chatziantoniou (2014) reported similar findings, emphasizing that stock markets of net oil importers (exporters) exhibited a negative (positive) response to oil price shocks. Based on a time-varying asymmetric quantile regression, Mokni (2020a) concluded that oil prices affect stocks asymmetrically, regardless of the position of the country. Nevertheless, they found that the stock markets of oil-importing countries were more responsive to negative oil shocks than to positive ones. Mokni (2020b) validated these results by a structural VAR model to identify oil supply and demand shocks. By analysing monthly data covering 1999-2018, he first demonstrated that stock returns respond more strongly to oil demand shocks than to supply shocks, and reported that stock markets in oil-exporting (importing) economies respond positively (negatively) to oil demand shocks (2008-2009, 2014-2016). It has been found that oil-exporting countries exhibited a negative reaction to shocks in oil supplies. Oil-importing countries, such as China and India exhibited no significant effects, while Japan and South Korea showed negative effects. Moreover, Silvapulle et al. (2017) found a positive relationship between oil prices and stock indices both before and after the Global Financial Crisis (GFC) for ten large net oil-importing countries.

Based on monthly data from five oil-exporting and eight oil-importing countries, Salisu and Isah (2017) demonstrated that a country's oil-trade position determines the magnitude of its reaction to price changes. According to empirical findings, oil export volumes are greater than non-exporters, suggesting that these countries are more vulnerable to fluctuations in oil prices. Despite this, they find that a positive oil price shock has a greater positive impact on oil-exporting countries than a negative one, after considering asymmetric effects through a nonlinear panel ARDL model. Additionally, a negative oil price shock leads to higher stock returns in oil-importing countries as compared to a positive oil price shock.

Additionally, stock returns and oil prices were directly correlated, as shown by the decline in oil prices during the COVID-19 pandemic. According to Prabheesh et al. (2020), they used daily data to analyse the correlation between oil prices and stock returns for four net oil-importing Asian economies (South Korea, India, China, and Japan). According to their empirical results, all stock returns increased between January 1 and June 8, 2020. However, the researchers observed that the correlation increases from February to March with a significant increase in uncertainty due to COVID-19.

According to one strand of literature, oil and stock market fluctuations may cause nonlinearity in the relationship (Ciner, 2001; Zhu et al., 2011; Aloui et al., 2012; Broadstock et al., 2012; Jiménez-Rodríguez, 2015; Jebran et al., 2017; Joo and Park, 2017; Huang et al., 2017; Roubaud and Arouri, 2018). Another advocated focusing on sectoral returns rather than aggregate stock returns, since fluctuations in oil prices may not affect every sector equally (Sadorsky, 2001; El-Sharif et al., 2005; McSweeney and Worthington, 2008; Nandha and Faff, 2008; Arouri and Nguyen, 2010; Gogineni, 2010; Narayan and Sharma, 2011; Mohanty et al., 2011, Elyasiani et al., 2011, 2013; Moya-Martínez et al., 2014; Sanusi and Ahmad, 2016; Kang et al., 2017; Badeeb and Lean, 2018; Uzo-Peters et al., 2018). Nandha and Faff (2008) use 35 industries as a basis for concluding that oil price shocks positively impact stock market returns in the global oil and gas industry. Moreover, similar results have been reported by Arouri and Nguyen (2010). They analysed oil prices and twelve European sector indices using the Granger causality test and a multifactor asset pricing model. The empirical results suggest that European oil and gas prices were highly sensitive to increases in crude oil price. By using a nonlinear ARDL estimation procedure and focusing on Islamic sectoral stocks globally, Badeeb and Lean (2018) demonstrated that, while the composite index was immune to oil price shocks, oil-gas industry stock returns responded both positively and negatively to increases in oil prices.

In contrast, Sadorsky (2001) concluded that increasing natural gas and crude oil prices positively affected Canadian energy stocks. According to Boyer and Filion (2007), rising crude oil and natural gas prices benefitted Canadian energy stocks. Additionally, El-Sharif et al. (2005) and Sanusi and Ahmad (2016) reported similar evidence in the United Kingdom for the oil and natural gas industry stocks. However, McSweeney and Worthington (2008) reported that oil prices have a strong positive impact on energy industry returns in Australia. Ramos and Veiga (2011) investigated the relationship between oil prices and the oil and gas industry in 34 developing and emerging economies. They reported that the oil-gas stock returns react strongly to oil price changes in developed countries, but asymmetrically in emerging markets. Moreover, Moya-Martinez et al. (2014) employed a multifactor model within a structural break to investigate possible structural breaks in the correlation between oil price changes and Spanish sectoral stock returns. In December 1998, they detected a structural break, resulting in a positive association between energy stocks and oil price shocks.

Lv et al. (2020) used the BEKK-GARCH methodology to study the impact of oil price volatility on stock volatility in the US and China, the two most important oil consumers. In the US, there is a bidirectional relationship between oil prices and stock returns, although this relationship varies from one subsector of the oil industry to another. Despite this, oil shocks in China only have unidirectional impacts due to the returns on oil stocks in subsectors. According to Uzo-Peters et al. (2018), oil price shocks have a significantly negative effect on Nigerian oil industry stock returns. Hoque and Low (2022) analysed industry-specific risks in Malaysia's oil and gas industry, which is also a net exporter. Following the same methodology as Moya-Martinez et al. (2014) and incorporating seven sub-industries within the oil and gas industry, they concluded that the effects of oil and gas prices vary between subindustries and over time. In contrast, Bagirov and Mateus (2022) emphasized the positive influence of Brent petrol prices on UK energy sector stock returns for oil-exporting (Mexico) and oil-importing (UK) countries. Degiannakis et al. (2013) examined the relationship between oil prices and ten

European sector returns using a time-varying multivariate heteroskedastic approach. Based on monthly Brent crude prices as a proxy for world oil prices, the researchers estimated time-varying correlations using a Diag-VECH GARCH model. Throughout the period (around 0.2-0.3), oil and gas industry returns were positively correlated with oil prices. Furthermore, although the level of correlation varied between different sub-periods (1992-1996; 1997-1999, 2000-2003, 2008-2010), the positive correlation between oil-gas sector stock returns and oil prices always remained positive, demonstrating the sector's indifference to the source of oil price fluctuations.

The majority of studies that examined BRIC countries focused on oil prices and overall stock market returns (Bhar and Nikolova, 2009; Ono, 2011; Fang and You, 2014; Bildirici and Badur, 2018; Ji et al. 2020) while a smaller number of studies focused on sectoral analysis without including the oil industry (Dogah and Premaratne, 2018). The fact that Brazil and Russia export oil, while India and China import it suggests that we can shed light on the differences in the trade positions of these countries by examining the effects of oil price fluctuations on the stock returns in the oil sector.

This study contributes to the literature by examining the risk factors affecting the oil-gas sector in BRIC countries. Furthermore, we use space-state models to analyse the impact of oil and natural gas price changes on oil-gas sectoral returns. To the best of our knowledge, few studies have examined the impact of natural gas prices on stock prices (Boyer and Filion, 2007; Acaravci et al., 2012; Mensi et al., 2021; Rizvi et al., 2022). According to Boyer and Filion (2007), natural gas prices positively impact oil and gas stock returns in Canada. Acaravci et al. (2012) investigated the long-run relationship between natural gas prices and stock price returns in EU countries and found indirect effects of natural gas prices on stock prices. Additionally, Mensi et al. (2021) employed a partial wavelet coherency method to assess BRICS countries' coherence. There is a greater co-movement between oil prices and stock markets than between natural gas prices and stock markets. Using a cross-sectional augmented autoregressive distributed lag model (CS-ARDL) Rizvi et al. (2022) demonstrated that oil and natural gas prices have an impact on equity returns in Brazil, China, India, Mexico, and South Africa (G5 economies). Over the period of 2013-2022, we expected various responses from BRIC countries regarding oil and natural gas prices. As a result of the Ukrainian-Russian war and the COVID-19 pandemic, the stock market returns in each country may also differ depending on shocks caused by changes in oil and natural gas prices.

The remainder of the study is organized as follows. The following section describes the data and methodology used in the study. Section 3 presents the empirical findings based on the asset pricing model estimation for the oil and gas sector in the BRIC economies. The final section concludes with a few remarks.

2. DATA AND METHODOLOGY

2.1. Methodology

This study utilizes the capital asset pricing model (CAPM) introduced by Sharpe (1964) and Lintner (1965), augmented with the risk factors affecting oil-gas sectoral stock returns of the BRIC countries. The CAPM model is widely used to analyse the significance of other risk factors, such as oil prices (Narayan and Sharma, 2011; Filis et al., 2011; Sanusi and Ahmad, 2016; Silvapulle et al., 2017), exchange rates (Karlsson and Hacker, 2013; Wen et al., 2019), and natural gas prices (Boyer and Filion, 2007; Rizvi et al., 2022). Therefore, the multifactor asset pricing model containing oil and natural gas prices excess returns is described as follows:

$$Roilgas_t = \alpha_0 + \beta_m Rm_t + \beta_{oil} Roil_t + \beta_{gas} Rgas_t + u_t \tag{1}$$

where $Roilgas_t$, Rm_t, $Roil_t$, and represent the excess returns in the oil-gas sector, the excess returns on the market, oil prices, and gas prices, respectively, at the time t. The market risk of the oil-gas sector is measured by β_m, which is known as market beta, while β_{oil} and β_{gas} denote the parameters of oil and natural gas prices, respectively. The following state-space equations are used to analyse the time-varying impact of oil prices on the oil-gas sector returns in the BRIC countries:

$$\begin{aligned} Roilgas_{it} &= \alpha_{0,t} + \beta_{m,t} Rm_t + \beta_{oil,t} Rpoil_t \\ &+ \beta_{gas,t} Rpgas_t + u_t \quad \mu_{it} \sim iid\left(0, \sigma^2_{\mu,t}\right) \end{aligned} \tag{2}$$

$$\alpha_{0,t} = \alpha_{0.t-1} + v_{\alpha.t} \quad v_{\alpha.t} \sim iid\left(0, \sigma^2_{v\alpha.t}\right) \tag{3}$$

$$\beta_{m.t} = \beta_{m.t-1} + v_{m.t} \quad v_{m.t} \sim iid\left(0, \sigma^2_{vm.t}\right) \tag{4}$$

$$\beta_{oil.t} = \beta_{oil.t-1} + v_{oil.t} \quad v_{oil.t} \sim iid\left(0, \sigma^2_{voil.t}\right) \tag{5}$$

$$\beta_{gas.t} = \beta_{gas.t-1} + v_{er.t} \quad v_{gas.t} \sim iid\left(0, \sigma^2_{gas.t}\right) \tag{6}$$

Equation (2) is known as the measurement equation. The transition equations that determine the behaviour of parameters that change over time are shown in equations (3)-(6). The model is based on Karlsson and Hacker (2013), Moya-Martinez et al. (2014), and Inchauspe et al. (2015), which assume a random walk process with the coefficients over time. Furthermore, the disturbances in the state equations are expected to be distributed independently and identically, with a zero mean and constant variance. The Kalman Filter is used to estimate the asset-pricing model using the maximum likelihood estimator (Kalman, 1960). It has numerous advantages over other nonlinear estimation methods. First, this model can adapt rapidly to changes in underlying states, as opposed to regression models. Moreover, parameter estimation does not require a fixed rolling window. Second, it can handle the time structure of the sensitivity coefficients. Furthermore, since the computations are recursive, there is no need for an ever-expanding memory source, even though the current estimation depends on the entire history of measurements.

The Kalman Filter can be used to estimate time-varying parameter models in three stages: Prediction, updating, and smoothing.[2] As part of the prediction stage, the optimal predicted value of the

2 The detailed description of the Kalman filter estimation procedure can be found in Kim and Nelson (1999) as well as Commandeur and Koopman (2007).

explained variable is determined based on the current information at time t–1. To update the estimated coefficients in the prediction stage, the prediction error is calculated by comparing the actual and predicted values of the dependent variable. Lastly, the state variables of the updating phase are based on the current value and historical data of the dependent variable. Based on this sample, smoothed estimates of time-varying parameters are calculated in the final step of the estimation process.

2.2. Data Description

This study examines the factors affecting the stock returns in the oil and gas sector of BRIC countries. The BRIC countries are selected for this study since they are considered to be the fastest-growing economies in the post-COVID-19 period. These countries allow us to distinguish between the possible impacts of oil and natural gas prices on stock returns based on the perspectives of oil exporters and oil importers. All data used in the estimations is obtained from the Thomson Reuters Datastream database.

As a proxy for the market price of natural gas, we use the Henry Hub pipeline price in the New York Mercantile Exchange, as it is based on the actual demand and supply of natural gas as a stand-alone commodity. In order to measure market risk, we use each the national (benchmark) stock market returns for each country. The data covered the period from January 29, 2013 to March 30, 2022. According to the previous section, CAPM measures the risk of factors affecting stock prices against risk-free returns. In this context, market returns, oil-gas sectors, oil prices, and gas prices are calculated as excess returns.

Table 1 presents the descriptive statistics of variables and the unit root test. All BRIC countries, except China, have negative oil-gas sectoral returns of similar magnitudes. Among the oil and gas sectors, the highest volatility is found in Brazil's stock return (0.049), while the lowest volatility is found in China's (0.021). Notably, oil-gas stock returns of Brazil, Russia, and China exhibit negative skewness with greater kurtosis values. According to Jarque-Bera test statistics, there is a significant non-normality in the return on investment, oil price, and gas price returns for the individual oil-gas sectors. According to the Augmented Dickey-Fuller (ADF) and Phillips-Perron unit tests, all variables are stationary, mainly at the 1% significance level.

3. EMPIRICAL RESULTS

First, this section estimates the linear asset-pricing model described by Equation (1). Table 2 illustrates how different sectors of the oil and gas industries respond differently to risk factors, including excess markets, oil prices, and natural gas prices. All countries have positive and significant linear market return coefficients.

Table 1: Descriptive statistics of the variables

Countries	Variables	Mean	Median	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis	Jarque-Bera	ADF	PP
Brazil	*Roilgasit*	−0.071	−0.067	0.178	−0.361	0.049	−0.307	3.698	86.216***	−4.076***	−55.768***
	Rmt	−0.071	−0.068	0.104	−0.223	0.041	0.001	2.549	20.295***	−2.949**	−37.044***
	Rpoilt	−0.072	−0.069	0.389	−0.668	0.049	−0.197	16.147	17242.580***	−3.886***	−55.130***
	Rpgast	−0.071	−0.070	0.230	−0.314	0.050	0.186	4.151	145.840***	−3.632***	−57.279***
Russia	*Roilgasit*	−0.078	−0.072	0.034	−0.471	0.038	−2.553	17.197	22469.780***	−2.975**	−23.340***
	Rmt	−0.078	−0.071	0.052	−0.549	0.038	−2.897	22.467	40718.500***	−2.802*	−24.620***
	Rpoilt	−0.079	−0.072	0.347	−0.702	0.047	−1.896	25.651	52061.930***	−4.440***	−50.901***
	Rpgast	−0.078	−0.074	0.241	−0.426	0.048	−1.039	9.719	4882.534***	−3.603***	−53.830***
India	*Roilgasit*	−0.065	−0.066	0.038	−0.192	0.023	0.000	4.308	170.537***	−2.986**	−49.597***
	Rmt	−0.065	−0.066	0.022	−0.198	0.021	0.012	3.767	58.696***	−2.704*	−32.404***
	Rpoilt	−0.065	−0.067	0.363	−0.693	0.036	−1.288	55.818	278701.900***	−6.809***	−65.485***
	Rpgast	−0.065	−0.067	0.293	−0.269	0.037	0.700	8.993	3774.678***	−5.229***	−65.764***
China	*Roilgasit*	−0.031	−0.028	0.058	−0.187	0.021	−1.300	8.837	4070.076***	−7.109***	−52.639***
	Rmt	−0.031	−0.028	0.036	−0.161	0.020	−1.772	9.827	5896.758***	−6.749***	−46.688***
	Rpoilt	−0.031	−0.028	0.399	−0.657	0.034	−1.867	69.713	444965.000***	−9.299***	−58.181***
	Rpgast	−0.031	−0.029	0.308	−0.258	0.035	0.090	9.934	4794.518***	−8.574***	−57.893***

This table presents the descriptive statistics of the oil-gas sector, market, oil prices, and gas prices for BRIC countries from January 29, 2013 to March 30, 2022. All variables are transformed into excess returns. Based on the skewness and kurtosis coefficients, the Jarque-Bera test shows a normal distribution in error terms. Augmented Dickey-Fuller (ADF) and Phillips-Perron unit root tests are employed for the model with a constant term. *, **, and *** show the statistical significance at the 10%, 5%, and 1% level, respectively

Table 2: OLS estimation results

Variable	Brazil	Russia	India	China
Constant	0.0050*** (0.0009)	−0.0004 (0.0006)	0.0015** (0.0007)	−0.0031*** (0.0005)
Rm_t	1.0990*** (0.0268)	0.9380*** (0.0291)	1.0140*** (0.0145)	0.8644*** (0.0221)
$Rpoil_t$	0.0600*** (0.0211)	0.0440*** (0.0138)	0.0075 (0.0094)	0.0266*** (0.0105)
$Rpgas_t$	−0.0820*** (0.0208)	0.0120 (0.0113)	0.0012 (0.0063)	0.0136 (0.0087)
Adjusted R-squared	0.8430	0.9750	0.7010	0.6974
SE.	0.0190	0.0060	0.0120	0.0117
Log-likelihood	6038.926	8765.855	7200.919	7253.321
F-stat	4281.345	30511.000	1854.323	1838.020
Pr. (F-stat)	0.000	0.000	0.000	0.000

Heteroscedasticity-Autocorrelation Consistent (HAC) standard errors are presented in parentheses. *, **, and *** represent the statistical significance at the level of 10%, 5%, and 1%, respectively

Moreover, Brazil has the riskiest oil and gas market, followed by India. However, the market betas of the remaining countries are less than one, indicating lower volatility and, therefore, lower risk than the overall market. With the expectation of India, all parameters of the oil price returns are significant. Brazil has a slightly higher parameter of oil price return than other countries, implying that its oil-gas sector might be more sensitive to the fluctuations in oil prices as a net oil-exporting country. Based on parameter estimates for natural gas price returns, there is no significant impact of changes in gas prices on the oil-gas sectors of BRIC countries, excluding Brazil. In Brazil, natural gas price returns negatively affect oil-gas stock returns.

It is important to analyse the stability of the linear model before estimating time-varying asset-price models. Based on the recursive extension of Chow's (1960) structural break test for unknown breakpoints, the Quandt likelihood ratio test (QLR) evaluates the parameter stability of equations (Quandt, 1960). The largest value of the Chow test statistic over the predetermined range is selected as the QLR statistic, indicating the most likely breaking date. Figure 1 presents the results obtained from the recursive estimates.

The null hypothesis of no structural break is rejected for all countries, since the test statistics exceed the five percent critical value. Linear estimation methodologies may lead to misleading conclusions regarding the statistical significance of the parameter estimates. Brazil and Russia have the most unstable asset-pricing behaviour, as the recursive test statistics mostly exceeded the five percent critical value. Moreover, Brazil reached the maximum value of QLR test statistics at the end of May 2017. The invasion of Ukraine caused serious parameter instabilities in Russia's asset-pricing equation, since higher values of test statistics were recorded before the outbreak of the war. The asset-pricing equation is relatively stable in India compared with other countries; however, the parameters of the equation exhibited unstable behaviour by the end of April 2020 as a result of the COVID-19 lockdown. Finally, China recorded the maximum value of the stability test statistics at the end of June 2015, which may be attributed to the decline in the excess returns of the market and oil-gas stock returns caused by the rise in market interest rates.

After validating the statistical significance of the structural breaks, we estimate the time-varying asset pricing models in Equations (2)-(6). Figure 2 displays the time-varying market values for the BRIC countries. All market beta values are significant and follow a relatively stable path compared to oil price and natural gas price coefficients. Among the BRIC countries, Brazil's oil and gas sector is the riskiest, with the coefficient of excess market return exceeding one in most of the analysis period. Its market beta is greater than unity in the beginning, reaching its highest value of 1.70 by the end of September 2014, when oil prices started falling below \$100. Following that, the market risk for Brazil's oil-gas market has declined gradually, in conjunction with the global decline in oil prices. Additionally, the COVID-19 outbreak has slightly increased the market risk for Brazil's oil-gas sector. The Indian oil-gas sector has the second-highest market beta coefficient, with the highest value of 1.223 in June 2014. The oil-gas market in China is considered the lowest risk, with a mean value of 0.773. Its market beta reached a maximum value of 1.14 in January 2015, similar to Brazil and India. Among the other countries, Russia has the most stable market value, with a mean value of 0.976. The greatest value of market risk was estimated to have occurred on March 10, 2020 because of the decline in oil prices related to COVID-19. At that time, oil prices had dropped below \$20 per barrel.

Unlike market returns, time-varying oil prices and natural gas parameters are significant in some cases. According to Figure 3, the most volatile oil price risk coefficient is obtained for Brazil. It ranges from −0.271 to 0.278, with a mean value of 0.063. In

Figure 1: (a-d) QLR stability test results

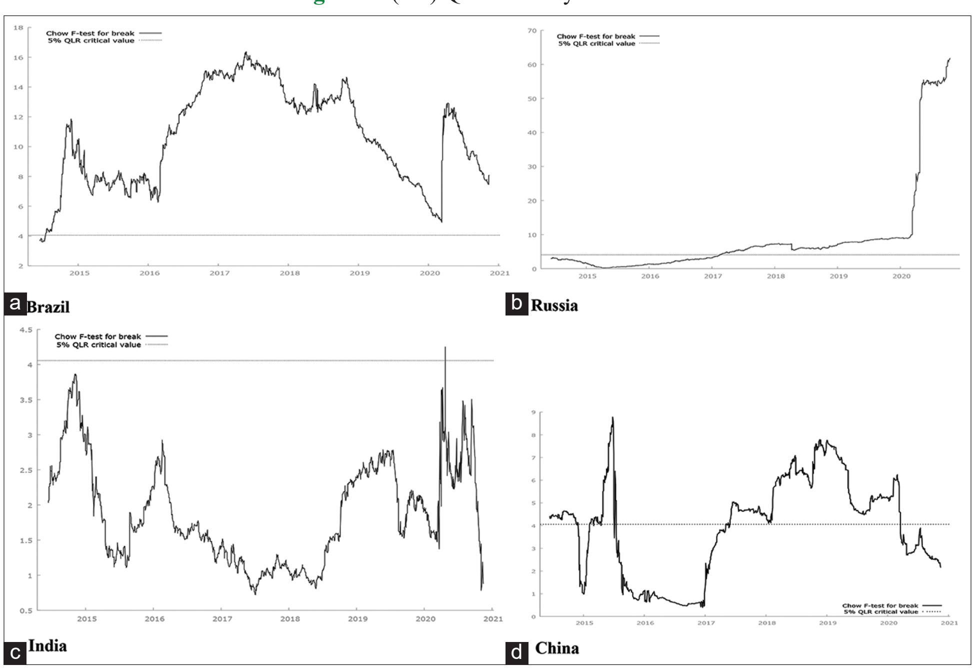


Figure 2: (a-d) Time-varying parameter estimates: Market risk

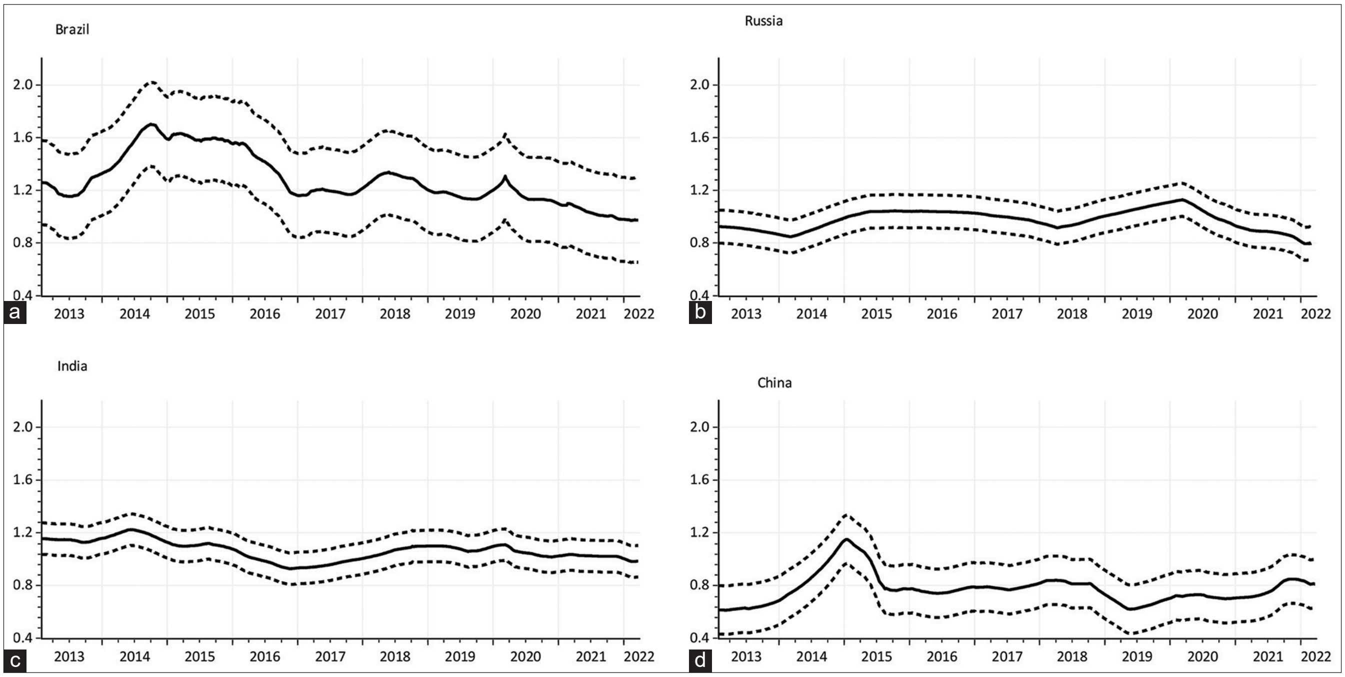
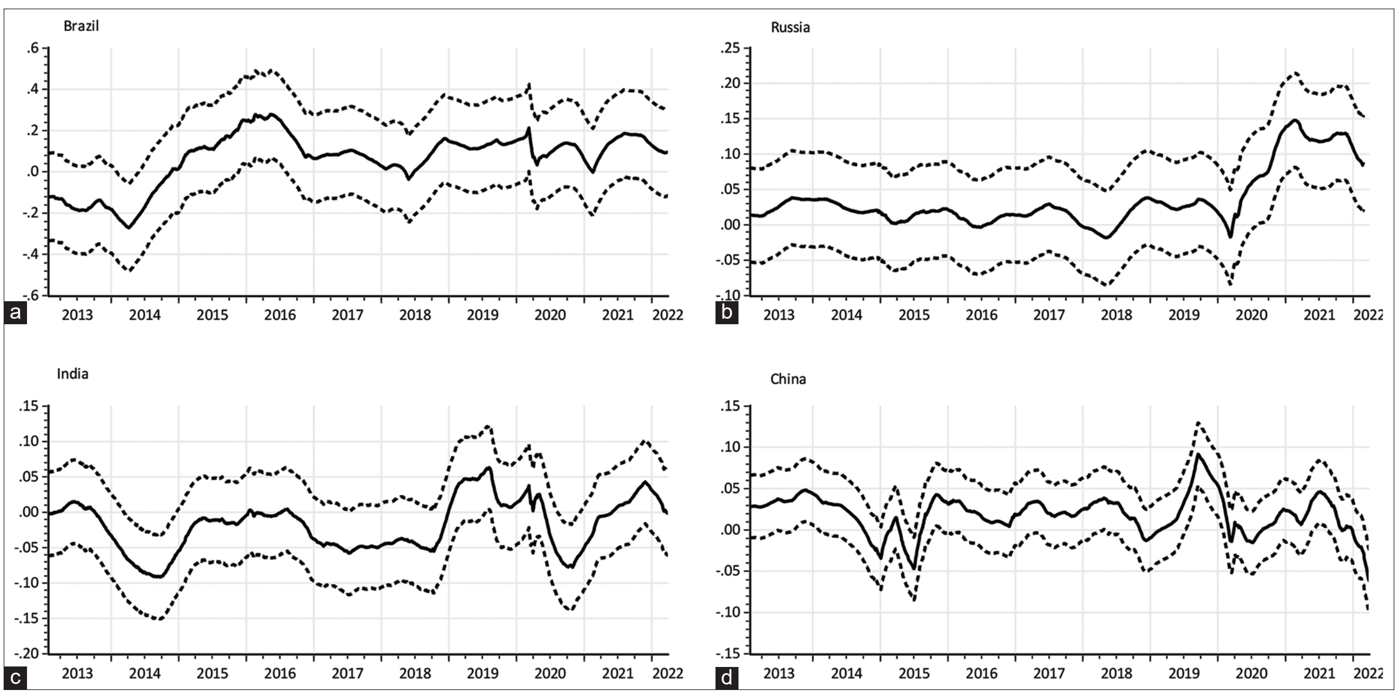


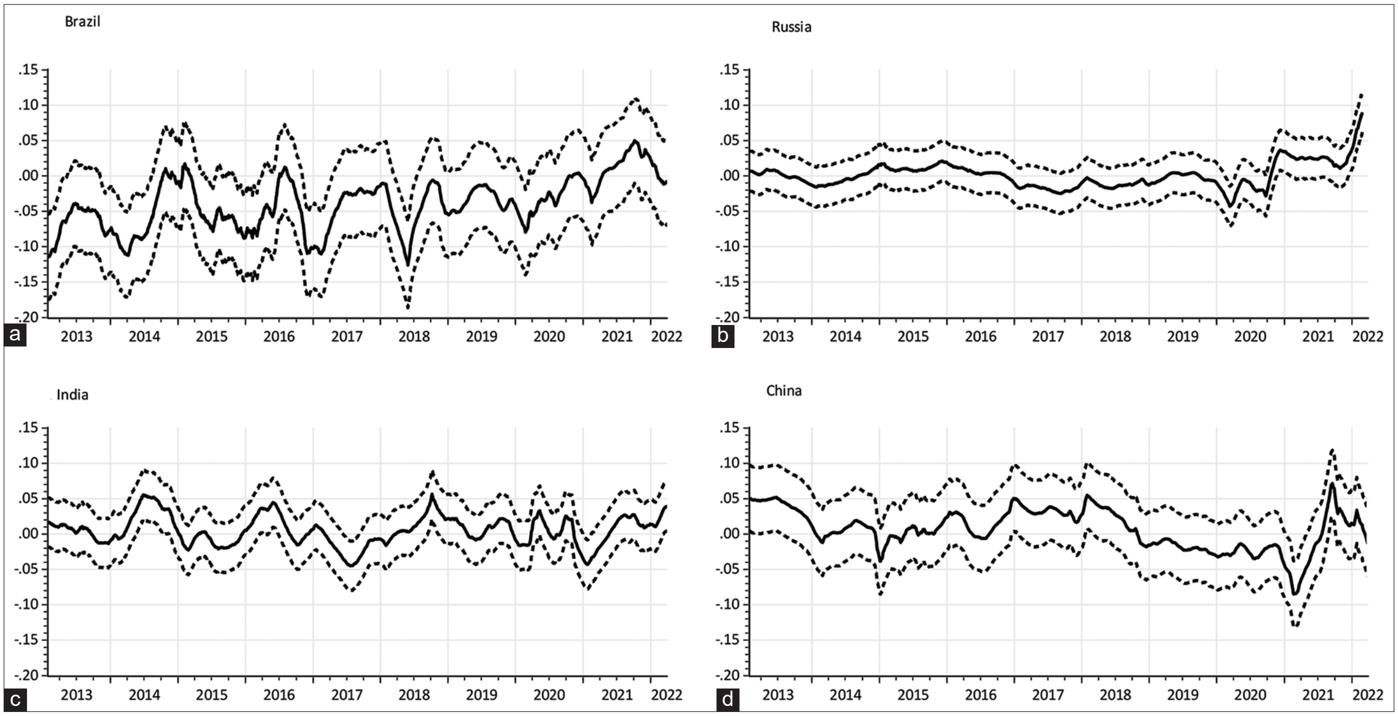
Figure 3: (a-d) Time-varying oil-price parameters



April 2014, oil prices dropped below \$50, resulting in the greatest adverse effect of oil price returns. In terms of oil price risk, Russia is ranked second. It should be noted that time-varying parameters are statistically significant only during the COVID-19 pandemic. During this period, Russia's time-varying parameter of oil price returns behaved similarly to Brazil's. Furthermore, as an oil importer, India is negatively affected by the oil price returns. Additionally, China's oil price risk was significantly and negatively affected in 2014-2015. During the earlier period of COVID-19, the Chinese oil and gas sector has benefited from the decline in oil prices. Despite this, the recent oil price crisis caused by the Russian-Ukrainian war has had a negative and significant impact on China's oil-gas stock return.

Unlike oil prices, the time-varying natural gas parameters have a lower magnitude and follow different patterns (Figure 4). For the majority of the analysis period, natural gas returns in Brazil negatively impact the oil-gas stock returns. However, the coefficient for the majority of the estimation sample is statistically insignificant. As opposed to oil prices, natural gas prices negatively impact Brazil's oil and gas sector. In contrast, natural gas and oil prices appear to have little impact on Russia's oil and gas industry. During

Figure 4: (a-d) Time-varying natural gas price parameters



the COVID-19 outbreak, natural gas prices fluctuated, negatively impacting the oil and natural gas industry. Moreover, natural gas prices have a positive impact at the end of the analysis period. It coincides with the beginning of the Russian-Ukrainian war. Shortly before the Ukrainian invasion, the Henry Hub spot price of natural gas increased from \$3.82 per million BTU at the end of December 2021 to \$6.12 per million BTU in the middle of February 2022. The natural gas price returns have both positive and negative significant effects on oil-gas stock returns in India. Initially, the effect of natural prices was not statistically significant. However, between May 2014 and December 2014, it became significant. The price of natural gas had a positive impact between February and June 2016, after which it changed into a negative impact in September 2016. Furthermore, the increase in natural gas prices has negatively affected the return on Indian oil-gas stocks between January 2021 and February 2021. Until June 2013, natural gas price returns had a positive and significant impact in China. During the COVID-19 period, natural gas prices reached their greatest impact. The negative and significant time-varying natural gas price parameters were observed between January 2021 and March 2021, which coincided with the period of high natural gas spot prices caused by the COVID-19 pandemic and cold weather conditions in Europe.[3]

4. CONCLUSION

This study examines the impact of oil and natural gas prices on the oil and gas sectors of the BRIC countries. To this end, we employ a time-varying and linear model of asset pricing, including returns on oil and natural gas. Our study is unique in various aspects. First, despite the fact that many studies have examined the effects of oil prices on stock returns, little attention has been paid to the effects of natural gas on stock returns. Moreover, our estimation sample, covering the period between January 29, 2013 and March 30, 2022, allows us to analyse the impact of the COVID-19 pandemic and the rising prices of oil and natural gas caused by escalating tensions between Russia and Ukraine, which resulted in a war.

All BRIC countries, except India, exhibit a positive impact of oil prices on oil-gas sectoral stock returns based on an estimation using a linear model. The positive relationship between oil prices and stock returns has also been reported by Boyer and Filion (2007), Park and Ratti (2008), Salisu and Isah (2017), and Silvapulle et al. (2017). The parameter of natural gas prices is statistically insignificant, with the exception of Brazil, where natural gas price returns negatively impact oil-gas stock returns. However, the structural break test demonstrated that such time-invariant parameter estimates may be misleading, since the null hypothesis that there is no structural break is rejected for all countries. According to recursive test statistics, Brazil and Russia have the most unstable oil and gas sectors. In particular, the invasion of Ukraine has led to serious parameter instabilities in the asset-pricing model of Russia.

After validating the statistical significance of the structural breaks, the time-varying asset pricing models are estimated. Based on the results, all market beta values are significant and exhibit relatively stable trends. Unlike market returns, time-varying oil prices and natural gas parameters are significant in certain cases. Brazil has the most volatile oil price risk coefficient, followed by Russia. Furthermore, Brazil and Russia, as oil-exporting countries, have positive time-varying oil price parameters, even though they are only significant in certain periods. The results for the two oil-importing countries,

3 Descriptive statistics for the time-varying parameters can be found in the Appendix 1.

China and India, differ. For instance, the oil-gas sector in India is the most negatively affected by oil price returns. Filis and Chatziantoniou (2014) as well as Salisu and Isah (2017) demonstrate that oil price shocks negatively impact stock returns. China has benefited from the decline in oil prices. In contrast, the energy crisis associated with the Russian-Ukrainian conflict adversely impacted the performance of oil and gas stocks. Time-varying natural gas parameters have a lower magnitude and are less significant than oil prices. As opposed to the positive effects of oil price returns, natural gas price changes negatively affect Brazil's oil and gas stock returns. These findings are consistent with the results of Rizvi et al. 2022 (at least in the short run). However, Boyer and Filion (2007) found positive impacts of natural gas on Canadian oil and gas stock returns. Despite being a major natural gas exporter, Russia's oil-gas sector is not significantly affected by natural gas prices. The only exceptions are the negative coefficients associated with the initial outbreak of COVID-19, and positive coefficients at the end of the analysis period, which coincided with the outbreak of the Russia-Ukraine war leading to spikes in natural gas spot prices. In the remaining the countries, India and China, natural gas price returns are less significant and exhibit both negative and positive signs. These effects can be attributed to the relatively high proportion of oil and coal in the energy mixes of both countries.[4] Moreover, our analyses indicate that, in contrast to Russia, the oil-gas sector of China is adversely affected by the increase in natural gas prices at the end of the analysis period due to the escalating conflicts between Russia and Ukraine.

This study has some limitations. First, the insignificant impact of natural gas prices in most countries compared to oil prices can be attributed to the Henry Hub pipeline price used for each country due to the unavailability of data on individual countries, which might be a poor proxy for natural gas prices. Since natural gas is transported at a high cost, and according to logistics, natural gas prices vary significantly between countries as compared to oil, which is traded on short-term contracts based on spot prices. Therefore, future studies should consider price differences when data on individual countries is available. Second, future studies should focus on the effects of coal on the stock market, since it accounts for a significant proportion of the energy mix of the BRIC countries. Finally, a similar analysis can be conducted after the Russia-Ukraine war to examine its effects on the stock markets of the countries affected by the war.[5]

4 As can be seen from Appendix 2, coal is the main source of energy for China and India as of 2021; they are ranked as the world's largest coal consumers, and coal comprises more than half of their energy mix. Furthermore, oil and coal are the two main energy sources, accounting for 74.07 percent and 83.25 percent of the final consumption of China and India, respectively.

5 Generally, refiners purchase crude oil three months in advance of delivery, based on short-term contracts at spot prices. Natural gas is usually transported through pipelines due to its gaseous nature. However, natural gas can be converted into liquefied natural gas (LNG) through a very expensive cryogenic processing process. LNG trade has increased as the global demand for natural gas has increased. However, the high cost and logistics associated with transportation have slowed the growth of LNG trade. Consequently, natural gas prices differ significantly between the countries.

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APPENDICES

Appendix 1: Descriptive statistics of the time-varying parameters

	Rm_t				$Rpoil_t$				$Rpgas_t$			
	Brazil	**Russia**	**India**	**China**	**Brazil**	**Russia**	**India**	**China**	**Brazil**	**Russia**	**India**	**China**
Mean	1.284	0.976	1.065	0.773	0.063	0.035	−0.019	0.019	−0.040	0.001	0.005	0.007
Median	1.216	0.987	1.068	0.764	0.099	0.022	−0.013	0.021	−0.041	0.000	0.005	0.007
Maximum	1.703	1.129	1.223	1.149	0.278	0.148	0.063	0.091	0.050	0.090	0.056	0.071
Minimum	0.971	0.786	0.926	0.612	−0.271	−0.018	−0.092	−0.047	−0.126	−0.043	−0.045	−0.085
Std. Dev.	0.192	0.076	0.072	0.112	0.129	0.040	0.036	0.022	0.037	0.017	0.021	0.028
Observations	2392	2369	2392	2392	2392	2369	2392	2392	2392	2369	2392	2392

Appendix 2: Primary energy consumption by source in BRIC countries

Country		Oil	Coal	Solar	Nuclear	Hydro	Wind	Gas	Other renewables	Total
Brazil	Consumption (TWh)	1237.88	197.91	43.84	36.92	949.38	189.15	404.46	430.91	3490.45
	Share (%)	35.46	5.67	1.26	1.06	27.20	5.42	11.59	5.03	100
China	Consumption (TWh)	8499.58	23936.06	855.65	1023.21	3401.68	1715.49	3786.94	572.27	43790.90
	Share (%)	19.41	54.66	1.95	2.34	7.77	3.92	8.65	1.24	100
India	Consumption (TWh)	2612.81	5580.15	178.73	110.28	419.52	178.18	621.68	139.87	9841.21
	Share (%)	26.55	56.70	1.82	1.12	4.26	1.81	6.32	1.15	100
Russia	Consumption (TWh)	1862.95	947.81	6.05	558.41	561.36	6.76	4746.14	4.13	8693.62
	Share (%)	21.43	10.90	0.07	6.42	6.46	0.08	54.59	0.02	100

Source: International Energy Agency, https://www.iea.org