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Oil prices and sectoral stock returns in the BRICS-T countries: A time-varying approach

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ABSTRACT

This paper investigates how exchange rates and oil prices have affected sectoral stock returns in the BRICS-T countries over the period from 2 January 2001 to 22 March 2021. Following the estimation of a benchmark linear model, Bai and Perron (2003) tests are carried out in each case to identify structural breaks, and then a state-space model with time-varying parameters is also estimated. The analysis shows that oil prices have a significant, positive effect on the energy sectors of all BRICS-T countries except India; a negative one on the industrial sectors of all countries except Turkey; a negative one on the financial sectors of Brazil, Russia, India, and South Africa; a negative one on the transportation sectors of India and Turkey and a positive one on that of Russia; finally, the most significant effect is on the chemicals sector, though it varies across countries. The subsamples and time-varying estimates indicate that exchange rate returns have a larger influence than oil price returns. Because energy-dependent sectors are vulnerable to global volatility, appropriate energy regulations should be implemented to reduce risk.

1. Introduction

Although the world's energy needs are increasingly being met by natural gas and coal, as well as renewable energy, crude oil remains a critical source, which still accounted for 31.2% of total energy consumption in 2020. For this reason, the effects of oil price volatility have remained an important research issue. In particular, various studies have investigated its effects on GDP growth (Bohi, 1991; Bergmann, 2019; Burbidge and Harrison, 1984; Gisser and Goodwin, 1986; Hamilton, 1983; Jiménez-Rodríguez and Sánchez, 2005; Lardic and Mignon, 2006), inflation (Bohi, 1991; Burbidge and Harrison, 1984; Cunado and De Gracia, 2005; Gisser and Goodwin, 1986; Hamilton, 1983); and exchange rates (Choudhri and Hakura, 2006; Goldfajn and Werlang, 2000; Hooker, 2002; Huang and Guo, 2007).

More recent studies, beginning with the seminal works of Huang et al. (1996) and Jones and Kaul (1996), have investigated how oil price fluctuations affect financial markets and highlighted various transmission channels (Moya-Martinez et al., 2014; Sadorsky, 1999). First, rising oil prices increase production costs, thereby reducing corporate profits and cash flows. Second, oil-price-induced inflationary pressures can affect the interest rate decisions of central banks and investor and consumer confidence. The resulting changes in the investment decisions of economic agents have an impact on asset values, such as stock market returns. Third, oil price shocks may affect macroeconomic variables and thus the discounted cash flows on which stock market values are determined (Arouri and Rault, 2012).

The present study aims to contribute to the literature in several respects. Firstly, the majority of studies so far have focused on developed stock markets (e.g., Apergis and Miller, 2009; Jones and Kaul, 1996; Lee and Zeng, 2011; Park and Ratti, 2008). In contrast, the present paper investigates how oil price fluctuations affect a group of less developed countries, specifically the BRICS stock markets (Brazil, Russia, India, China, and South Africa) and Turkey (BRICS-T). These countries include both oil importers (China, India, South Africa, and Turkey) and oil exporters (Russia and Brazil). This enables us to test for differences between these two types of economies with different trade patterns. The second novel feature of our study compared to most previous ones is that it uses sectoral rather than aggregate data since sectors such as

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chemicals, energy, and transportation may be more sensitive to oil price shocks than others. We also test for possible structural breaks and estimate sectoral asset-pricing models over the corresponding sub-samples in addition to the full sample estimates. The third contribution is to use a specification that allows for time variation in the model parameters and thus enables us to highlight the structural changes brought about by events such as financial crises, changes in the global energy market, and the current COVID-19 pandemic.

The layout of the paper is structured as follows. The next section briefly reviews previous studies, while the following three sections present the data, methodology, and empirical findings. After summarizing the main findings, the final section summarizes the main findings and discusses their policy implications.

2. Literature review

As already mentioned, most studies concerning the effects of oil price changes on stock returns have focused on developed economies. Their results differ depending on the country, estimation sample, and type of variable used in the analysis. Jones and Kaul (1996), for example, found that changes in oil prices Granger cause output and real stock returns in Canada, Japan, the US, and the UK. Both the US and Canadian stock markets appear to behave rationally since oil shocks affect stock prices purely by influencing current and expected future real cash flows. Puzzlingly, however, oil price shocks in Japan and the UK do not predict future cash flows and/or financial variables, although they are generally a good proxy for variability in expected returns. Focusing on eight developed countries (Australia, Canada, France, Germany, Italy, Japan, the UK, and the US), Apergis and Miller (2009) found that stock market returns were affected by three types of structural shocks (aggregate demand, oil demand, and oil supply). The exception was Australia. Other variables such as interest and exchange rates turned out to be good predictors of future values. Miller and Ratti (2009) provided evidence of changes in the long-run relationship between the world price of crude oil and international stock markets in some OECD countries.

Only a few papers have focused on developing economies. For instance, Cunado and De Gracia (2005) showed that economic activity and price indices are significantly affected by oil price shocks in Japan, Singapore, South Korea, Malaysia, Thailand, and the Philippines, whereas the effects on national currencies are smaller in the short run. From their estimation of an international factor model for the Asia-Pacific region, Nandha and Hammoudeh (2007) found that stock returns were most sensitive to oil price changes in the Philippines and South Korea, whilst in India, Indonesia, Malaysia, New Zealand, Singapore, and Taiwan, they were more related to exchange rates. Ramos and Veiga (2011) concluded that returns in the oil and natural gas industry are significantly increased by oil price shocks and that industries in developed countries are more affected by oil price risk than those in developing countries. Furthermore, oil industry returns exhibit an asymmetric response to oil price fluctuations. Alamgir and Amin, 2021 analyzed both the short- and long-run relationships between stock price indices and crude oil prices by using data for the South Asian countries over the period 1997–2021 and estimating a panel Nonlinear Autoregressive Distributed Lag Model (NARDL). Their results indicated that the stock market index and world oil prices are positively correlated, while positive oil price shocks have a larger effect than negative ones.

Other studies have compared oil importers and exporters to determine if they are affected differently by oil shocks (Jiménez-Rodríguez and Sanchez, 2005). Wang et al. (2013), for example, found significant differences between the two types of countries regarding their reaction to oil shocks in terms of amplitude, duration, and direction. The effect also depended on the source of the shock (demand or supply factors). Their VAR estimates indicate that both short- and long-run stock returns are more strongly affected by oil price shocks in oil-exporting than oil-importing countries. Hammoudeh and Aleisa (2004) reported spillovers from the oil market to the stock market in major oil exporters. According to Park and Ratti (2008), oil price increases have a positive effect on real stock returns in Norway, which is an oil exporter. In the case of European oil exporters, there is little evidence of asymmetric effects on stock returns of positive and negative oil price shocks. Arouri and Rault (2012) and Hammoudeh and Choi (2006) analyzed the case of the oil exporter, Cooperation Council for the Arab States (Gulf) member countries using VAR and panel cointegration approaches. They obtained contradictory results. In particular, the former study reported that there is a direct impact of US Treasury interest rates but not US stock indices on some Gulf markets, whereas the latter reported that stock returns increase in line with oil prices, except in Saudi Arabia. Considering the world's main oil exporters (Canada, Mexico, Norway, Russia, the UK, Kuwait, Saudi Arabia, and the United Arab Emirates), Basher et al. (2018) identified four types of oil market shocks: flow oil supply, flow oil demand, speculative oil-demand, and oil-market-specific. Using a Markov-switching framework, they found that, apart from the case of Mexico, one or more of the four types of shocks significantly affected stock returns.[1]

Other studies (e.g., Boyer and Filion, 2007; Cong et al., 2008; El-Sharif et al., 2005; Elyasiani et al., 2011; Gogineni, 2010; Huang et al., 1996; McSweeney and Worthington, 2008; Narayan and Sharma, 2011; Pal and Mitra, 2019; Sadorsky, 2001) have focused on sectoral or firm-level stock returns since oil prices may have different effects depending on each sector's dependence on oil. For instance, Huang et al. (1996) applied the VAR methodology to US data to examine how stock returns are affected in specific sectors by oil price changes. The only significant linkage was in the case of oil corporations. Gogineni (2010) and Narayan and Sharma (2011) reported that US stock returns are affected to a different extent depending on how much the particular sector depends on oil and how large the company is. Elyasiani et al. (2011) concluded that US sectoral stock returns face a systemic asset price risk from variations in oil prices. Furthermore, stock return volatility has a long memory in some industries. Sadorsky (2001) showed that oil and natural gas stock prices in Canada are both increased by market and oil price risk factors. Conversely, rising exchange rates or widening term spreads reduce them. Boyer and Filion (2007) corroborated these findings and concluded that the market beta values of Canadian oil and gas corporations are lower than one and that the systematic market risk of the energy firms is less than that of the whole stock market. By contrast, El-Sharif et al. (2005) show that various risk factors impact oil and natural gas stock returns in the UK. Specifically, rising oil prices (exchange rates) generally increase (decrease) stock market returns. Focusing on Australia, McSweeney and Worthington (2008) used multi-factor models to examine how macroeconomic factors affect sectoral stock returns. They found that oil price changes had a positive effect in the energy sector, whereas the effect was negative in the banking, retail, and transportation sectors. In addition, profits for banking and finance stocks were significantly affected by exchange rate changes. In one of the few sectoral studies analyzing developing markets, Cong et al. (2008) found that China's real stock returns were not significantly affected by oil price shocks, except for some oil corporations and the manufacturing sector. Pal and Mitra (2019) used wavelet analysis to examine the link between oil price shocks and four major stock indices for vehicle manufacturers and only found co-movement over the periods 2000–2002 and 2006–2009.

Another strand of the literature, albeit mostly focused on developed markets, advocates the use of nonlinear specifications to capture potential time-varying relationships between oil price shocks and stock market responses. These may occur owing to structural changes (e.g., Arouri and Nguyen, 2010; Aloui et al., 2012; Broadstock et al., 2012;

[1] An impulse-response analysis based on the VAR model is another method for detecting the response of an economic variable to a shock. More information can be found in Idrovo-Aguirre and Contreras-Reyes (2021).

Elyasiani et al., 2013; Filis et al., 2011; Jammazi and Aloui, 2010; Jawadi et al., 2010; Jiménez-Rodríguez, 2015; Joo and Park, 2017; Maghyereh and Al-Kandari, 2007; Moya-Martinez et al., 2014; Zhu et al., 2011). For example, using the Double-Threshold FIGARCH model, Elyasiani et al. (2013) examined how oil price shocks affect US manufacturing and financial industry stock returns. They concluded that the effect is smaller when the oil market is less volatile. Moya-Martinez et al. (2014) used a multi-factor model allowing for time variation and obtained similar results for the Spanish economy. They reported that the degree of exposure to oil prices varies significantly by industry and was quite low during the 1990s, when price sensitivity on the Spanish stock exchange was very low owing to low oil prices. Broadstock et al. (2012) investigated the time-varying oil price-stock return relationship in China and concluded that the Chinese stock market has been more vulnerable to international crude oil market shocks following the 2008 financial crisis. Furthermore, there has been a longitudinal change in the relationship between oil price changes and energy market stock returns. Using panel data, Li et al. (2012) found structural breaks and a reversal in the direction of causality between oil and Chinese stock prices as a result of the global financial crisis.

Jammazi and Aloui (2010) carried out wavelet analysis for the UK, France, and Japan. They found that stock returns were unaffected by crude oil shocks during recessions (except in Japan) but significantly reduced during periods of stock market expansion. Applying a multi-factor asset pricing model and Granger causality tests to the US and twelve European countries, Arouri and Nguyen (2010) reported that oil price changes and stock returns are significantly correlated in most European countries. On the other hand, stock returns in specific sectors are significantly different in terms of their structure and sensitivity to shocks. Jammazi (2012) also used wavelet analysis to model the volatility of real crude oil prices. Aloui et al. (2012) found that stock returns are asymmetrically sensitive to oil prices. More specifically, returns are positively correlated with oil price changes if emerging markets are divided into three groups based on oil dependency. Jiménez-Rodríguez (2015) estimated VAR models to test for possible nonlinear relationships between real oil prices and real stock returns. They found that oil shocks had a greater effect on stock returns in stable price environments. Furthermore, all countries exhibited a negative relationship between shocks and returns. Maghyereh and Al-Kandari (2007) found no long-term linear relationship between stock markets and oil prices, although there was evidence of nonlinear cointegration for developing oil-exporting countries. Jawadi et al. (2010) reported significant nonlinear cointegration in both developed and developing markets for oil and stock returns, which is important information for investment strategies. Zhu et al. (2011) detected long-run positive correlations between oil prices and stock prices. Using the DCC-GARCH-GJR approach, Filis et al. (2011) found that the time-varying correlation between oil and stock prices differed between oil importers and exporters. Joo and Park (2017) found that, at least during some sub-periods, oil price uncertainty has time-varying effects on both stock and oil returns.

Most studies of BRICS-T countries have focused on how oil prices affect aggregate stock returns. Shahzad et al. (2021), for example, used the time-varying optimal copula (TVOC) method to show multiple tail dependence between crude oil prices and BRIC stock markets. Moreover, the risk of spillovers from oil prices was greater for oil exporters than for oil importers. Focusing on both the Gulf Cooperation Council and BRICS economies, Umar et al. (2021) found a moderately strong relationship between equity markets and oil price shocks in terms of both returns and volatility. Using a local Gaussian correlation to compare data from BRICS countries before and after the COVID-19 pandemic, Yuan et al. (2021) provided evidence that oil prices and stock markets are interdependent and contagious and that the relationship is asymmetric. Using bootstrap methods, they also showed a significant increase in contagion during the pandemic period (in particular, India's oil market affected its stock market while West Texas Intermediate (WTI) futures affected Russia's stock market). The only exception was China.

To our knowledge, there are only two sectoral studies related to BRICS-T countries: Çatık et al. (2020), who estimated an augmented asset-pricing model for 12 listed stock market sectors in Turkey, reported parameter time variation and sectoral differences, as well as a greater impact of exchange rate changes compared to oil price shocks; and Yurteri Kösedağlı et al. (2021) focused on the BRICS and also found a time-varying relationship between oil prices as well as exchange rates and oil-gas sectoral stock returns, which is positive in all cases except Indonesia.

3. Data and methodology

3.1. Data

The effects of oil prices on the sectoral stock indices of the BRICS-T countries are analyzed using daily data covering the period from 2 January 2001 to 22 March 2021. The sectors included in the analysis are energy, industrials, chemicals, transportation, and financial sectors. The estimation sample reflects data availability for the corresponding series. These have been obtained mainly from the Refinitiv Datastream database (Refinitiv Eikon Datastream, 2022) and, in a few cases, from other sources. In particular, for Russia, the chemicals, transportation, and industrials stock indices are taken from Red Star Financials, and the basic materials stock index from the FTSE; for South Africa, the transportation index also comes from the FTSE; finally, all data for Turkey were collected from BIST. Nominal exchange rates vis-à-vis the US dollar are employed. The benchmark stock market indices are the BOVESPA index for Brazil, the Shanghai Stock Exchange index for China, the NIFTY 500 for India, the MOEX for Russia, the FTSE/JSE index for South Africa and the BIST 100 index for Turkey. The following interest rate series are used: the Interbank deposit certification rate for Brazil, the 3-month deposit rate for China, the 1-month deposit rate for India, the 3-month deposit rate for Russia, the 1-month deposit rate for South Africa, and the 1-month deposit interest rate for Turkey. Finally, the proxy for global oil prices is the Europe Brent Spot Price Free on Board (USD Per Barrel).[2]

In its original specification (Sharpe, 1964; Lintner, 1965), the CAPM model focuses on an asset's excess returns above the risk-free rate. Thus, before proceeding to the estimation, the excess returns on total and sectoral stock prices, Rex_{it}, are computed using the following formula:

$$Rex_{it} = \frac{SP_{it} - SP_{it-1}}{SP_{it-1}} - int_t \tag{1}$$

where SP_{it} is the sectoral stock price of sector i, and int_t is the daily risk-free interest rate. Excess returns for the stock market as a whole, Rm_t, oil prices, $Roil_t$, and exchange rates, Rer_t, are also calculated in the same way.

Table 1 reports the descriptive statistics and unit root tests for all series. Average returns are positive for most sectors but vary across countries. The highest volatility is exhibited by Brazil's energy sector (0.025), China's chemical sector (0.017), India's transport sector (0.022), Russia's finance sector (0.021), South Africa's energy sector (0.022), and Turkey's chemical sector (0.027). For all countries except China the industrial sector has the lowest volatility. There is high negative skewness and high kurtosis in the sectoral return series. The Jarque-Bera test statistics indicate that these series as well as oil prices and exchange rates are not normally distributed. Finally, the Augmented Dickey-Fuller and Phillips-Perron unit root tests indicate that all variables are stationary at the 1% significance level.

[2] Appendix Table A1 provides a detailed description of the dataset.

Table 1
Descriptive statistics and unit root tests for the individual variables.

Countries	Descriptive statistics									Unit Root Tests	
	Sectors	Mean	Median	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis	Jarque-Bera	ADF	PP
Brazil	*Chemicals*	1.86×10^{-5}	-3×10^{-4}	0.210	−0.267	0.023	−0.900	20.055	64645.82***	−70.527***	−70.516***
	Energy	-1.66×10^{-6}	-19×10^{-5}	0.190	−0.307	0.025	−0.580	13.156	22963.75***	−73.827***	−73.826***
	Finance	6.96×10^{-5}	-22×10^{-5}	0.137	−0.125	0.017	0.024	8.796	7384.695***	−70.875***	−70.857***
	Industry	234×10^{-6}	-17×10^{-5}	0.124	−0.197	0.016	−0.798	18.296	51986.85***	−76.113***	−76.055***
	*Transportation**	251×10^{-6}	-31×10^{-5}	0.199	−0.310	0.023	−0.636	17.081	41559.96***	−73.591***	−73.890***
	Oil Price	1×10^{-4}	-17×10^{-5}	0.412	−0.644	0.026	−2.197	92.606	1768990***	−14.620***	−71.826***
	Exchange Rate	-11×10^{-5}	-31×10^{-5}	0.096	−0.118	0.010	0.099	12.823	21215.43***	−52.714***	−69.390***
	Market Return	7.10×10^{-5}	-18×10^{-5}	0.136	−0.160	0.018	−0.399	10.539	12631.14***	−74.249***	−74.370***
China	*Chemicals*	7.59×10^{-5}	-4.65×10^{-5}	0.092	−0.107	0.018	−0.414	6.226	2438.078***	−67.761***	−67.893***
	Energy	-7.62×10^{-5}	-5.37×10^{-5}	0.095	−0.217	0.018	−0.163	13.344	23541.84***	−73.476***	−73.473***
	Finance	$6.50E \times 10^{-5}$	-5.37×10^{-5}	0.095	−0.101	0.017	0.029	7.805	5075.467***	−72.431***	−72.430***
	Industry	-17×10^{-5}	-4.65×10^{-5}	0.095	−0.097	0.017	−0.441	7.614	4850.236***	−69.204***	−69.492***
	*Transportation**	-2.29×10^{-5}	-4.65×10^{-5}	0.095	−0.101	0.016	−0.386	8.519	6824.93***	−70.145***	−70.212***
	Oil Price	16×10^{-5}	-3.00×10^{-5}	0.412	−0.644	0.026	−2.202	92.670	1771526***	−15.239***	−73.607***
	Exchange Rate	-9.63×10^{-5}	-4.65×10^{-5}	0.018	−0.020	0.001	−0.158	27.741	134557.4***	−72.678***	−74.156***
	Market Return	4.37×10^{-5}	-3.00×10^{-5}	0.094	−0.093	0.015	−0.411	8.519	6844.411***	−71.865***	−71.970***
India	*Chemicals*	298×10^{-6}	-8.31×10^{-5}	0.107	−0.784	0.019	−14.733	616.059	82797554***	−66.010***	−66.689***
	Energy	308×10^{-6}	-15×10^{-5}	0.165	−0.165	0.017	−0.483	13.398	23970.31***	−67.690***	−67.668***
	Finance	367×10^{-6}	4.63×10^{-5}	0.184	−0.178	0.018	−0.426	12.906	21725.81***	−66.121***	−65.993***
	Industry	426×10^{-6}	428×10^{-6}	0.158	−0.145	0.016	−0.381	10.782	13439.2***	−67.088***	−67.848***
	*Transportation**	587×10^{-6}	-18×10^{-5}	0.537	−0.179	0.023	2.597	67.650	924563.5***	−73.166***	−73.174***
	Oil Price	2.65×10^{-5}	-12×10^{-5}	0.412	−0.644	0.026	−2.201	92.642	1770432***	−15.225***	−73.600***
	Exchange Rate	-1×10^{-4}	-21×10^{-5}	0.032	−0.031	0.004	0.286	9.925	10612.29***	−29.392***	−69.878***
	Market Return	31×10^{-5}	603×10^{-6}	0.150	−0.137	0.014	−0.748	14.540	29760.79***	−66.968***	−67.429***
Russia	*Chemicals*	-26×10^{-5}	-16×10^{-5}	0.167	−0.313	0.019	−1.077	25.009	107485.7***	−67.036***	−66.910***
	Energy	333×10^{-6}	-12×10^{-5}	0.274	−0.222	0.020	−0.025	21.889	78419.8***	−72.203***	−72.248***
	Finance	761×10^{-6}	-13×10^{-5}	0.283	−0.233	0.022	0.035	18.537	53058.97***	−71.057***	−71.216***
	Industry	415×10^{-6}	12×10^{-5}	0.289	−0.215	0.017	0.026	33.741	207701.2***	−70.097***	−70.118***
	Transportation	173×10^{-6}	-16×10^{-5}	0.260	−0.358	0.020	−1.191	44.526	380256.9***	−28.547***	−71.464***
	Oil Price	-2.12×10^{-6}	-11×10^{-5}	0.412	−0.644	0.026	−2.204	92.638	1770297***	−15.221***	−73.601***
	Exchange Rate	-3.07×10^{-5}	-27×10^{-5}	0.142	−0.156	0.008	0.492	61.623	755567.1***	−23.101***	−70.216***
	Market Return	39×10^{-5}	2.47×10^{-5}	0.252	−0.207	0.019	−0.335	22.974	87788.42***	−71.799***	−71.798***
South Africa	*Chemicals*	219×10^{-6}	-21×10^{-5}	0.188	−0.139	0.018	0.351	11.871	17403.73***	−71.876***	−72.111***
	Energy	1×10^{-4}	-17×10^{-5}	0.220	−0.431	0.022	−1.327	36.191	243685.2***	−66.150***	−66.363***
	Finance	5.61×10^{-5}	-16×10^{-5}	0.082	−0.146	0.014	−0.388	10.436	12286.02***	−53.158***	−70.392***
	Industry	-3.07×10^{-7}	-16×10^{-5}	0.088	−0.261	0.014	−1.263	30.459	167120.8***	−72.973***	−73.062***
	Transportation	-14×10^{-5}	-29×10^{-5}	0.113	−0.117	0.017	−0.132	7.276	3833.882***	−69.638***	−69.633***
	Oil Price	6.24×10^{-6}	-14×10^{-5}	0.412	−0.644	0.026	−2.201	92.637	1770235***	−69.891***	−70.066***
	Exchange Rate	-7.90×10^{-5}	-29×10^{-5}	0.098	−0.085	0.011	0.291	7.486	4498.575***	−68.743***	−68.713***
	Market Return	191×10^{-6}	-29×10^{-5}	0.072	−0.102	0.012	−0.321	8.374	6437.357***	−68.641***	−68.603***
Turkey	*Chemicals*	796×10^{-6}	-25×10^{-5}	0.190	−0.216	0.027	0.170	9.868	10392.15***	−69.687***	−69.666***
	Energy	-11×10^{-5}	-19×10^{-5}	0.153	−0.182	0.021	−0.150	8.679	7107.998***	−72.646***	−72.652***
	Finance	118×10^{-6}	-28×10^{-5}	0.146	−0.207	0.023	−0.131	8.067	5658.025***	−70.629***	−70.625***
	Industry	4.09×10^{-5}	-7.7×10^{-5}	0.128	−0.199	0.019	−0.386	10.899	13845.12***	−71.049***	−71.056***
	Transportation	189×10^{-6}	-22×10^{-5}	0.122	−0.184	0.024	−0.342	7.667	4889.515***	−47.906***	−72.208***
	Oil Price	-24×10^{-5}	-19×10^{-5}	0.412	−0.644	0.026	−2.201	92.612	1769235***	−15.220***	−73.644***
	Exchange Rate	1.58×10^{-5}	-35×10^{-5}	0.373	−0.164	0.012	7.051	229.802	11349581***	−54.583***	−65.460***
	Market Return	5.75×10^{-5}	-3.5×10^{-6}	0.125	−0.201	0.019	−0.409	10.955	14056.65***	−72.413***	−72.419***

Note: This table shows the sectoral data of 6 countries and descriptive statistics of oil price, exchange rate, and market return from January 2, 2001, to March 22, 2021. Jarque-Bera test is determined by the coefficients of skewness and kurtosis, and shows the normal distribution in error terms. Augmented Dickey-Fuller (ADF) and Phillips-Perron unit root tests are employed for unit root tests. *, **, and *** show the statistical significance at the 10%, 5%, and 1% level. (* Brazil - transport sector data starts from 05 to 02–2002; ** South Africa - transport sector data ends on 20-03-2020).

3.2. Methodology

The linear form of the multi-factor asset pricing model is as follows:

$$Rex_{it} = \beta_{i0} + \beta_{im}Rm_t + \beta_{ioil}Roil_t + \beta_{ier}Rer_t + u_{it} \tag{2}$$

where Rex_{it} is the excess return for the i-th sector and Rm_t, $Roil_t$ and Rer_t are the excess returns for the stock market as a whole, oil prices, and exchange rates, respectively. The parameter β_{im} stands for the market beta, which quantifies the systematic risk of sector i's returns relative to the market; β_{ioil} and β_{ier}, on the other hand, measure the sensitivity of sectoral returns to oil prices and exchange rate shocks.

We also conducted endogenous Bai and Perron (1998, 2003) structural break tests in order to check stability of the asset-pricing models. Specifically, m breaks are allowed for by adopting the following specification:

$$\begin{array}{ll} Rex_{it} = \beta_{i0} + \beta_{im}Rm_t + \beta_{ioil}Roil_t + \beta_{ier}Rer_t + u_{it}, & t = 1, \ldots, T_1 \\ \vdots & \vdots \\ Rex_{it} = \beta_{i0} + \beta_{im}Rm_t + \beta_{ioil}Roil_t + \beta_{ier}Rer_t + u_{it}, & t = T_m, \ldots, T_1 \end{array} \tag{3}$$

where corresponds to the timing of the endogenously determined structural breaks. The model is estimated using OLS in the following form:

$$\sum_{i=1}^{m+1} \sum_{T_{t-1}+1}^{T_1} (Rex_{it} - \beta_{i0} - \beta_{im}Rm_t - \beta_{ioil}Roil_t - \beta_{ier}Rer_t)^2 \tag{4}$$

According to Bai and Perron (1998, 2003), three tests should be performed to specify the maximum number of breaks, namely $supF_T(k)$, $UD_{max} - WD_{max}$, and $supF_T(l+1/l)$. $supF_T(k)$ is an F-statistic used to test the null hypothesis of no structural breaks with a given number of breaks (k) as the alternative. Given an upper bound $M(1 \le m \le M)$, UD_{max} and WD_{max}test the null hypothesis of no structural breaks against the alternative of an unknown number of breaks. Sequential $supF_T(l+1/l)$ tests the null hypothesis of l versus $l+$ 1breaks.

Having detected endogenous structural breaks in the asset-pricing models, we allow for the possibility that oil price and exchange rate returns have time-varying effects on sectoral stock returns. The linear version of the asset pricing model can be re-written as the following time-varying state-space model:

$$Rex_{it} = \beta_{i,t}^{\alpha} + \beta_{i,t}^{m}Rm_t + \beta_{i,t}^{oil}Roil_t + \beta_{i,t}^{er}Rer_t + \mu_{it} \; \mu_{it} \sim i.i.d \left(0, \sigma_{\mu,t}^2\right) \tag{5}$$

$$\beta_{i,t}^{\alpha} = \beta_{i,t-1}^{\alpha} + \varphi_{\alpha.t} \; \varphi_{\alpha.t} \sim i.i.d \left(0, \sigma_{\varphi\alpha.t}^2\right) \tag{6}$$

$$\beta_{i,t}^{m} = \beta_{i,t-1}^{m} + \varphi_{m.t} \; \varphi_{m.t} \sim i.i.d \left(0, \sigma_{\varphi m.t}^2\right) \tag{7}$$

$$\beta_{i,t}^{oil} = \beta_{i,t-1}^{oil} + \varphi_{oil.t} \; \varphi_{oil.t} \sim i.i.d \left(0, \sigma_{\varphi oil.t}^2\right) \tag{8}$$

$$\beta_{i,t}^{er} = \beta_{i,t-1}^{er} + \varphi_{er.t} \; \varphi_{er.t} \sim i.i.d \left(0, \sigma_{\varphi er.t}^2\right) \tag{9}$$

Equation (5) is the measurement equation, while Equations (6)–(9) are the transition equations with the time-varying coefficients. Following Inchauspe et al. (2015), Karlsson and Hacker (2013), Moya-Martinez et al. (2014) we assume that the time-varying coefficients follow a random walk without drift. The variances of the transition equations are denoted by $\sigma_{\mu,t}^2$, $\sigma_{\varphi\alpha.t}^2$, $\sigma_{\varphi m.t}^2$, $\sigma_{\varphi oil.t}^2$ and $\sigma_{\varphi er.t}^2$. Finally, the error terms are assumed to be independently and identically distributed with a zero mean and homoscedastic variance.

To estimate the aforementioned time-varying parameter model, we apply a Kalman (1960) filter following the maximum-likelihood method. Following Durbin and Koopman (2001), the state-space model can be re-written as the following matrix:

$$Rex_{it} = \psi(z_t)\xi_t + \varepsilon_t \; \varepsilon_t \sim n.i.d\left(0, \sigma_{\varepsilon t}\right) \tag{10}$$

$$\xi_t = \psi(z_t)\xi_{t-1} + \xi_t \; \vartheta_t \sim N(0, Q_t) \tag{11}$$

where $\psi(z_t) = [1 \quad Rex_t \quad Roil_t \quad Rer_t]$ is the matrix of explanatory variables, and $\xi_t^{'} = \left[\beta_{i,t}^{\alpha} \quad \beta_{i,t}^{m} \quad \beta_{i,t}^{oil} \quad \beta_{i,t}^{er}\right]$ is the vector of state variables, including the time-varying coefficients. $\varepsilon_t = \mu_{it}$ is the vector of the error terms of the measurement equation; $\vartheta_t^{'} = [\varphi_{\alpha.t} \; \varphi_{m.t} \; \varphi_{oil.t} \; \varphi_{er.t}]$ is the vector of the error terms of the state equations with a $Q_t = [\sigma_{\varepsilon\alpha.t}^2 \; \sigma_{\varepsilon m.t}^2 \; \sigma_{\varepsilon oil.t}^2 \; \sigma_{\varepsilon er.t}^2]$ variance-covariance matrix.

Kalman filtering is applied in three steps to estimate the state-space models: prediction, updating, and smoothing. The first step is to derive the dependent variable's estimated value using the available information at $t-1$ with the state vector, $\xi_t|\mathrm{t}-1$ and its covariance matrix, $P_t|\mathrm{t}-1$. The second step involves a comparison of the actual and predicted values of the state variables to update the inference about ξ_t obtained in the first step. In the third step, information from the entire forecast sample is applied to obtain the corrected coefficient estimates.[3]

The above-mentioned time-varying state-space specification has several significant advantages over the other alternatives. First, unlike the regression model, the time-varying structure of the model adjusts quickly to any abrupt or smooth changes in the underlying states; parameter estimation does not require a fixed-size rolling window (Bentz et al., 2002). Second, as Durbin and Koopman (2001) demonstrated, recursive estimation of the state-space model provides a better fit using the Kalman filter, particularly when the data have structural breaks, missing observations, and outliers. Finally, similar to GARCH specifications, the effects of unexpected shock size changes can be quantified from the time-varying disturbance terms in the measurement and state equations.[4]

4. Empirical results

Table 2 reports the results for the benchmark linear asset pricing model. In all industries, there are highly significant market return (market beta) coefficients. By contrast, the estimates for oil price and exchange rate returns are only significant for some industries. Except for India, the energy sector is significantly and positively affected by oil prices. The linear estimates also indicate a significant difference in the effect of oil prices on the energy sector. That is, apart from South Africa, oil exporters are affected much more than oil importers. The financial sector is affected similarly by oil prices in both oil importers and exporters, with the most strongly affected countries being South Africa and Brazil. Regarding the energy sector, the two oil exporters in the sample, Brazil and Russia, show a positive and significant effect of oil price changes. Conversely, their impact is negative in India and South Africa, and non-significant in China and Turkey, in line with the financial sector results. Oil prices do not affect the transportation sector in Brazil, China, and South Africa; but have a negative effect on India and Turkey, and a positive effect on Russia. The effect on the chemical sector was insignificant in Turkey, positive in South Africa, Russia, and China, and negative in India and Brazil.

It has been argued in the literature that failing to account for nonlinearities and structural breaks in asset pricing behavior may result in biased parameter estimates (Choudhry, 2005; Karlsson and Hacker, 2013; Kilian and Vigfusson, 2013; Moya-Martinez et al., 2014). Therefore, we follow the Bai and Perron (1998, 2003) approach to check for structural breaks. The results presented in Table 3 indicate at least two significant structural breaks for all countries in the sectoral asset pricing models. The most breaks occurred in Brazil's energy sector, China's chemical sector, and India's financial sector. There are various breaks in all sectors in Russia, and at least two in each case in South Africa. In

[3] For further information on Kalman filtering, see Commandeur and Koopman (2007) and Kim and Nelson (1999).

[4] Choudhry and Wu (2008) also showed that state-space models provide better forecasting power than the alternative specifications.

Turkey, the industrial and transportation sectors had the most breaks. The sub-sample estimation results indicate a consistent pattern. That is, despite differences in the size of the estimated coefficients across sub-samples, exchange rate returns are clearly a more important determinant of sectoral returns than oil price changes in most cases, as already revealed by previous studies (El-Sharif et al., 2005; Park and Ratti, 2008).

Having established that all countries have significant structural breaks, the asset-pricing model with time-varying parameters provided by (5)-(9) is estimated to examine in more depth how the influence of risk variables on sectoral stock returns in the BRICS-T countries evolves over time. [5] In line with previous studies (e.g., Gogineni, 2010; McSweeney and Worthington, 2008; Moya-Martinez et al., 2014; Narayan and Sharma, 2011), we extend the time-varying state-space model with up to five lags of exchange rates and oil prices, corresponding to a five-day working week.[6] The estimated time-varying parameters are shown in Figs. 1–5. To assess their significance over time, we plot the cumulative sum and two-standard deviation confidence intervals of the oil and exchange rate parameters up to the fifth lag. The results generally support the structural break test results. That is, there are significant variations, both over time and between industries and countries, in the way sectoral stock returns are affected by oil prices and exchange rates. Further evidence on the variation in the coefficients is provided by the descriptive statistics in Table 4.

Before examining each sector's sensitivity to changes in oil and exchange rate returns, we investigate the market risk of each sector using the time-varying sectoral market return coefficients shown in panel (a) of Figs. 1–5. The parameters are positive and significant for all countries, with their estimated value being less than one in the majority of cases. However, the estimated value is greater than one for Brazil's energy sector, China's chemical and industrial sectors, India's financial and industrial sectors, Russia's energy, financial, and industrial sectors, South Africa's energy sector, and Turkey's financial sector. This implies that the risk for these sectors is greater than the overall market.

The time-varying exchange rate and oil price parameters are shown in panels (b) and (c) of Figs. 1–5. The shaded regions indicate the periods when the parameters are significant. These show that exchange rates have a greater effect than oil prices in most sectors of the countries under consideration. More specifically, this is true for all sectors in India and Russia; all except energy in Brazil and China; the transportation, financial, and industrial sectors in South Africa; and the chemicals, finance, and transportation sectors in Turkey.

Fig. 1 displays the results for the chemicals industry, which is expected to be significantly affected by oil prices owing to the heavy use of petroleum products as an input in production. However, there are clear differences across countries. In Brazil, the effects of oil prices were negative and significant in the early 2000s but not significant in the remaining period. The Chinese chemical sector is not initially affected by oil price changes, but the 2008 global financial crisis and changes in oil prices in 2010 and 2018 have a positive and significant effect. In India (Russia), the effect is initially positive (negative) and significant but then becomes insignificant. The South African chemical industry appears to be the most affected by changes in oil prices. The time-varying parameter on oil price changes has an average value of 0.099 and ranges between-0.059 and 0.330. Between 2015 and 2019, oil prices had a significant positive impact. However, this effect disappeared during the COVID-19 pandemic before reappearing at the beginning of 2021, when it reached its highest value. In Turkey, oil prices initially had a significant negative impact, though the cumulative impact of the estimated parameters is insignificant.

Exchange rate fluctuations have the largest impact on the chemical sector stock returns in Brazil and Russia. In the former, the effect was negative and significant before the 2008 global financial crisis. In the latter, it was negative and significant till 2011. In India, there was a negative and significant impact in 2004 and during the global financial crisis, but none at other times. In China, there was a positive and significant impact between 2008 and 2011, and a negative one during the COVID-19 pandemic. Finally, the effect of the exchange rate in South Africa is positive and significant, and peaked in early 2017.

Fig. 2 shows the results for the energy sector. It appears that oil prices play a more important role than exchange rates in all countries considered except India. Their effect is positive and significant in Brazil in 2004–2009 and 2015–2019, and in China in 2010–2013 and 2015–2020, but insignificant in India throughout the sample period. It was particularly significant in Russia and in South Africa. In the latter, the average value was 0.254, ranging between −0.047 and 0.761. It peaked in March 2020 during the COVID-19 pandemic. In Turkey, the effect was positive and significant only during the 2008 global financial crisis but insignificant at other times. The exchange rate had a positive effect in Brazil initially but a negative one in 2014–2015. In China, the effect was significant and negative in 2005–2006 and positive in

Table 2
OLS estimation results.

Countries	Sectors	Oil Price	Exchange Rate	Market Return	R^2
Brazil	*Chemicals*	0.008	−0.047	0.626***	0.228
	Energy	0.137***	0.003	1.060***	0.608
	Finance	−0.022***	−0.152***	0.790***	0.790
	Industry	0.020***	−0.027*	0.587***	0.459
	Transportation	−0.007	−0.215***	0.654***	0.275
China	*Chemicals*	0.010***	−0.047	0.996***	0.714
	Energy	0.010*	0.227**	0.903***	0.590
	Finance	−0.005	−0.107	0.985***	0.787
	Industry	−0.004	−0.003	1.034***	0.851
	Transportation	−0.003	−0.088	0.892***	0.662
India	*Chemicals*	−0.012	−0.040	0.743	0.303
	Energy	0.007	−0.043	0.999***	0.624
	Finance	0.000	−0.302***	1.121***	0.792
	Industry	−0.011***	−0.062**	1.040***	0.821
	Transportation	−0.008	−0.021	0.799***	0.234
Russia	*Chemicals*	−0.004	−0.059**	0.325***	0.105
	Energy	0.045***	0.045***	0.953***	0.800
	Finance	−0.019***	−0.355***	0.913***	0.648
	Industry	0.023***	0.011	0.820***	0.782
	Transportation	0.020**	0.042	0.474***	0.196
South Africa	*Chemicals*	0.052***	−0.019	0.465***	0.119
	Energy	0.127***	0.049**	1.130***	0.432
	Finance	−0.037***	−0.328***	0.803***	0.539
	Industry	−0.018***	−0.233***	0.709***	0.435
	Transportation	0.012	−0.296***	0.619***	0.253
Turkey	*Chemicals*	0.011	−0.045	0.777***	0.299
	Energy	0.016**	0.094***	0.895***	0.646
	Finance	$2.09*10^{-5}$	−0.056***	1.113***	0.852
	Industry	0.000	0.062***	0.842***	0.651
	Transportation	−0.027***	−0.001	0.873***	0.477

Note: This table displays the OLS estimates for each country's five sectors. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

[5] The stability of the estimated time-varying parameter models is investigated with several tests. The results of the normality test in general indicate that the residuals of the models are not normally distributed. However, histogram of the residuals indicate that the distribution of the residuals follows symmetrical pattern as the skewness statistics are close to zero. Furthermore, we checked the stability of the residuals using the CUSUM (Cumulative sum of recursive residuals) test of Brown et al. (1975) and found that the models are not subject to serious parameter instabilities. Therefore, one can conclude that time-varying parameter models provide a good fit in terms of dealing with structural breaks in the data. The results of the CUSUM test are available upon request.

[6] We have checked the robustness of the time-varying coefficient results by using different number of lags and found that the signs of the estimated parameters are the same, though their size tends to increase with the inclusion of extra lags. These results are not included in the paper but are available upon request.

Table 3
Bai-Perron estimation results.

Countries	Sectors	Breaks	Sub Samples	Constant (c)	Oil Price	Exchange Rate	Market Return
Brazil	*Chemicals*	4	1/02/2001–1/09/2009	−0.000	−0.033*	−0.179***	0.505***
			1/12/2009–5/19/2014	0.000	−0.006	−0.044	0.784***
			5/20/2014–2/07/2018	0.001	0.052*	0.173**	0.471***
			2/08/2018–3/22/2021	0.000	0.009	0.09	0.940***
	Energy	5	1/02/2001–2/18/2005	0.000	0.070***	0.115***	0.606***
			2/21/2005–10/29/2008	0.000	0.241***	0.211***	0.996***
			10/30/2008–10/25/2013	0.000	0.061***	−0.062	1.052***
			10/28/2013–12/06/2016	0.000	0.256	−0.035	1.758***
			12/07/2016–3/22/2021	0.000	0.083***	−0.023	1.311***
	Finance	3	1/02/2001–12/15/2005	8.20×10^{-5}	−0.007	−0.232***	0.515***
			12/16/2005–5/27/2014	6.30×10^{-5}	−0.035***	−0.042*	0.845***
			5/28/2014–3/22/2021	0.000	−0.037***	−0.143***	0.984***
	Industry	4	1/02/2001–3/27/2006	0.000	0.011	0.000	0.378***
			3/28/2006–12/20/2011	0.000	0.000	−0.087***	0.613***
			12/21/2011–8/01/2016	0.000	−0.011	0.041	0.508***
			8/02/2016–3/22/2021	0.000	0.016*	−0.021	0.873***
	Transportation	4	2/05/2002–10/19/2005	0.000	−0.010	−0.311***	0.230***
			10/20/2005–10/30/2008	-3.94×10^{-5}	−0.046	−0.059	0.782***
			10/31/2008–12/02/2013	0.000	0.003	−0.055	0.436***
			12/03/2013–3/22/2021	0.000	−0.016	−0.241***	0.983***
China	*Chemicals*	4	1/02/2001–1/18/2006	0.000	0.004	0.691	1.064***
			1/19/2006–11/20/2009	0.000	0.005	0.256	0.871***
			11/23/2009–8/27/2015	0.000	0.059***	0.166	1.016***
			8/28/2015–3/22/2021	4.40×10^{-5}	0.001	0.062	1.169***
	Energy	3	1/02/2001–4/30/2008	0.000	0.017	0.644*	1.015***
			5/01/2008–6/26/2015	0.000	0.002	0.128	0.888***
			6/29/2015–3/22/2021	0.000	0.017**	−0.019	0.723***
	Finance	3	1/02/2001–4/10/2012	-5.32×10^{-6}	−0.008	−0.223	1.008***
			4/11/2012–4/24/2015	0.000	−0.013	0.049	1.129***
			4/27/2015–3/22/2021	1.84×10^{-5}	0.002	−0.216**	0.871***
	Industry	3	1/02/2001–6/30/2004	−0.001***	−0.012	−8.642	0.858***
			7/01/2004–1/13/2011	-5.15×10^{-5}	−0.008	0.416***	1.016***
			1/14/2011–3/22/2021	-1.71×10^{-5}	−0.003	0.031	1.117
	Transportation	3	1/02/2001–2/15/2007	3.98×10^{-5}	0.004	0.065	0.791***
			2/16/2007–7/29/2015	-2.66×10^{-5}	−0.011	0.304	0.961***
			7/30/2015–3/22/2021	0.000	−0.001	−0.293***	0.814***
India	*Chemicals*	2	1/02/2001–1/29/2004	0.000	−0.060***	0.537	0.469***
			1/30/2004–3/22/2021	0.000	−0.009	0.557	0.805***
	Energy	2	1/02/2001–1/13/2004	0.001***	0.008	0.014	0.922***
			1/14/2004–3/22/2021	0.000	0.006	−0.021	1.016***
	Finance	4	1/02/2001–1/28/2004	0.000**	0.000	−0.134	0.748***
			1/29/2004–2/14/2008	9.83×10^{-5}	−0.003	−0.331***	1.078***
			2/15/2008–2/05/2015	0.0000	−0.039***	−0.079**	1.333***
			2/06/2015–3/22/2021	-5.90×10^{-5}	0.003	−0.155**	1.196***
	Industry	3	1/02/2001–1/15/2004	0.000	0.001	−0.417*	1.128***
			1/16/2004–2/07/2007	0.000**	0.001	−0.069	0.958***
			2/08/2007–3/22/2021	2.90×10^{-5}	−0.014***	−0.063**	1.041***
	Transportation	3	1/02/2001–11/27/2007	0.001	−0.047**	0.374*	0.635***
			11/28/2007–1/28/2014	0.000	0.004	0.080	0.783***
			1/29/2014–3/22/2021	0.000	−0.010	−0.067	1.168***
Russia	*Chemicals*	4	1/02/2001–9/29/2005	0.000	−0.034	−0.344	0.103***
			9/30/2005–4/15/2009	0.000	−0.040*	−0.335***	0.349***
			4/16/2009–12/27/2012	0.000	0.101**	0.092	0.692***
			12/28/2012–3/22/2021	0.000*	−0.010	0.009	0.196***
	Energy	4	1/02/2001–4/04/2006	0.000	0.065***	−0.452***	0.819***
			4/05/2006–9/16/2011	0.000	0.039***	0.118***	1.015***
			9/19/2011–12/25/2014	4.15×10^{-5}	0.037	0.035	0.874***
			12/26/2014–3/22/2021	-8.75×10^{-5}	0.029***	0.065***	1.074***
	Finance	4	1/02/2001–10/24/2005	0.001***	0.001	−0.649***	0.649***
			10/25/2005–3/13/2009	0.000	−0.071***	−0.132	0.982***
			3/16/2009–7/26/2012	0.000	−0.055*	−0.270***	1.170***
			7/27/2012–3/22/2021	-6.78×10^{-5}	−0.025***	−0.331***	0.959***
	Industry	4	1/02/2001–11/23/2005	0.000***	0.014	−0.279**	0.507***
			11/24/2005–10/13/2011	0.000	0.013	−0.030	0.943***
			10/14/2011–1/04/2018	-8.58×10^{-5}	0.008	0.056***	0.832***
			1/05/2018–3/22/2021	6.19×10^{-5}	0.013**	0.058*	0.961***
	Transportation	4	1/02/2001–10/21/2008	0.000	0.025	−0.405**	0.356***
			10/22/2008–12/12/2014	0.000	0.014	−0.094	0.644***
			12/15/2014–1/29/2018	0.000	0.058*	0.301***	0.411***
			1/30/2018–3/22/2021	0.000	−0.011	−0.211***	0.392***
South Africa	*Chemicals*	3	1/02/2001–2/24/2015	0.000	0.009	−0.072***	0.309***
			2/25/2015–3/07/2018	-8.46×10^{-5}	0.203***	0.247***	1.101***
			3/08/2018–3/22/2021	0.000	0.037***	0.011	0.806***

(*continued on next page*)

Table 3 (*continued*)

Countries	Sectors	Breaks	Sub Samples	Constant (c)	Oil Price	Exchange Rate	Market Return
	Energy	4	1/02/2001–5/04/2004	0.000	0.102***	0.208***	0.834***
			5/05/2004–10/02/2014	7.11×10^{-5}	0.122***	0.014	1.102***
			10/03/2014–3/07/2018	0.000	0.224***	0.218***	1.164***
			3/08/2018–3/22/2021	0.000*	0.096***	−0.041	1.359***
	Finance	4	1/02/2001–10/19/2005	0.000	−0.014	−0.232***	0.655***
			10/20/2005–1/30/2009	0.000	−0.133***	−0.305***	−0.730***
			2/02/2009–10/19/2015	0.000	−0.059***	−0.147***	0.869***
			10/20/2015–3/22/2021	0.000	−0.028***	−0.583***	0.997***
	Industry	4	1/02/2001–6/10/2005	-9.19×10^{-5}	−0.022*	−0.166***	0.559***
			6/13/2005–3/07/2013	1.77×10^{-6}	−0.013	−0.081***	0.681***
			3/08/2013–8/15/2016	4.80×10^{-5}	−0.047***	−0.326***	0.977***
			8/16/2016–3/22/2021	0.000**	−0.021***	−0.483***	0.820***
	*Transportation**	4	1/02/2001–1/12/2006	0.000	0.007	−0.089**	0.232***
			1/13/2006–4/29/2013	-9.19×10^{-5}	−0.018	−0.223***	0.677***
			4/30/2013–9/26/2016	0.000	0.004	−0.505***	1.018***
			9/27/2016–3/20/2020	0.000	0.007	−0.336***	0.700***
Turkey	*Chemicals*	3	1/02/2001–7/01/2005	-4.49×10^{-5}	−0.012	−0.056	0.737***
			7/04/2005–1/20/2009	0.002***	0.043	−0.540***	0.774***
			1/21/2009–3/22/2021	0.000	0.006	0.180***	0.803***
	Energy	3	1/02/2001–2/06/2004	0.000	−0.041**	0.152***	0.950***
			2/09/2004–12/01/2015	-7.83×10^{-5}	0.021*	−0.036	0.804***
			12/02/2015–3/22/2021	0.000	0.025***	0.076**	0.946***
	Finance	3	1/02/2001–5/03/2004	0.000	0.012	−0.032**	1.076***
			5/04/2004–1/08/2018	-8.43×10^{-5}	−0.007	−0.002	1.164***
			1/09/2018–3/22/2021	0.000	0.001	−0.185***	1.065***
	Industry	4	1/02/2001–2/24/2005	2.46×10^{-5}	−0.007	0.041**	0.986***
			2/25/2005–9/10/2008	9.31×10^{-5}	−0.001	−0.158***	0.587***
			9/11/2008–6/12/2013	0.000	−0.005	−0.220***	0.756***
			6/13/2013–3/22/2021	-3.19×10^{-6}	0.006	0.187***	0.732***
	*Transportation**	4	1/02/2001–1/19/2004	0.000	−0.077***	0.068**	0.797***
			1/20/2004–9/09/2009	6.67×10^{-5}	−0.023	−0.235***	0.665***
			9/10/2009–7/15/2016	0.000	−0.113***	−0.069	1.012***
			7/18/2016–3/22/2021	0.000	−0.009	0.074	1.291***

Note: This table shows the results of the subsample estimates obtained from Bai-Perron methodology, including the number of breaks and the break dates for every sector and country. *, **, and *** show the statistical significance at the 10%, 5%, and 1% level.

2015–2016. It was greater than the corresponding impact of oil prices. In India, the effect was significant and negative for most of the sample period. In Russia, it was positive and most significant in 2008–2014, where it peaked in 2018–2019. Finally, its effect was least significant in Turkey, as the coefficients were only significant and positive during 2018–2019.

Fig. 3 shows the findings for the financial sector. Oil prices had an adverse and significant impact on all countries. During the 2008 global financial crisis, Russia and Brazil both experienced the largest negative impact. In the former, this parameter is highly significant between 2005-2008 and 2009–2010, with an average value of −0.074, ranging between −0.225 and 0.079. In the latter, the average value was −0.049, ranging between −0.104 and 0.012. Its minimum values coincide with those of the 2005–2009 period (see Table 4). The exchange rate also has a negative effect on all countries' financial sectors, except Russia's. The most significant time-varying exchange rate parameters are found for Brazil and South Africa. In Turkey, exchange rate returns have a negative and significant influence only during 2018, which corresponds with a period of economic turmoil that resulted in considerable hikes in exchange rates.

Fig. 4 displays the time-varying parameters for the industrial sector. In Brazil, both oil prices and the exchange rate had a negative and significant impact only during the 2008 global financial crisis. In China, only oil prices had a negative and significant effect during 2008–2013. In India, the exchange rate had a negative and significant impact between 2001 and 2004, while in South Africa the effect was most significant and negative between 2005 and 2007. The average was −0.354, ranging between-0.687 and-0.187, with a peak in April 2020 during the COVID-19 pandemic. In Russia, there was a negative impact at the start of the sample period, but this became positive in 2005–2006. There was no significant effect on industrial stock returns in Turkey.

Finally, Fig. 5 shows the results for the transportation sector, which is significantly affected by oil price changes. In terms of the significance of time-varying parameters, China, India, and Turkey are the most affected countries. More specifically, in China, the effect is negative till 2018, peaking during the 2008 global financial crisis period, with an average value of-0.016 and a range between-0.027 and-0.002. In India, the effect was negative until the 2008 financial crisis. In Turkey, transportation is the sector most adversely affected by oil price fluctuations. The average value of this parameter is −0.104, ranging between −0.279 and 0.076. The exchange rate has a significant negative and significant effect in all countries except China, which was positive and significant between 2001 and 2012, especially in Russia, South Africa (between 2004 and 2019), and India. In Turkey, there was a significant negative effect only during the 2008 global financial crisis.

5. Conclusions

This study has investigated how oil prices and exchange rates affect sectoral stock returns in the BRICS-T countries. For this purpose, capital asset pricing models, including market returns, oil prices, and exchange rate returns as the main risk factors that may affect stock returns, were estimated using daily data covering the period from 2 January 2001 to 22 March 2021. We analyzed the presence of structural breaks using the Bai and Perron (2003) approach. Finally, we applied the Kalman (1960) filter to estimate state-space models with time-varying parameters.

The Bai and Perron (2003) tests confirm that there were structural breaks in the data, which implies that inference based on the benchmark linear model would be misleading. The parameter estimates for the sub-samples identified through multiple break tests suggested that in all countries considered, exchange rate returns affect the majority of sectors more than oil price returns. These findings agree with those reported by earlier studies (El-Sharif et al., 2005; Park and Ratti, 2008).

The parameter estimates indicate that the effects of oil prices and

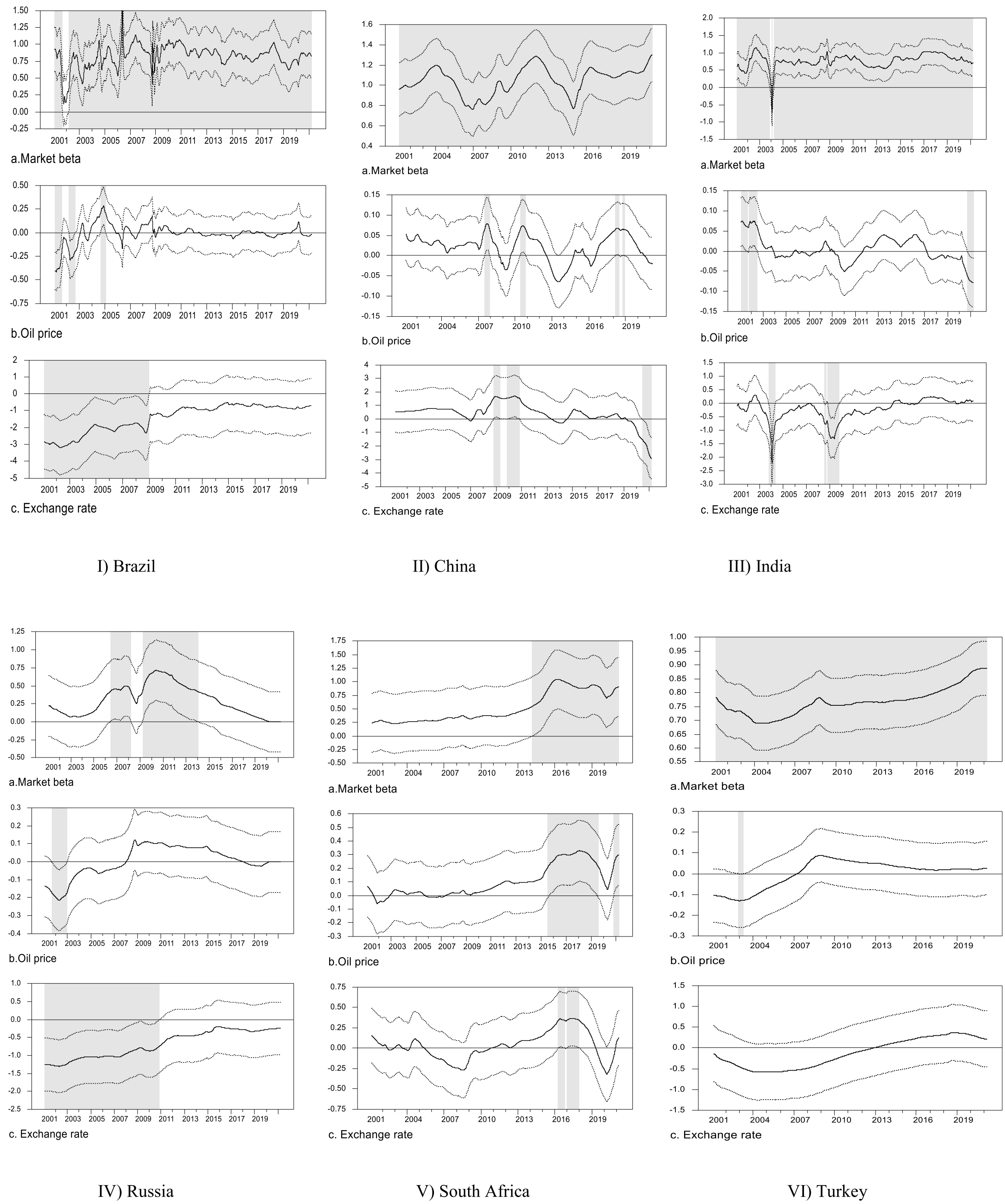


Figure 1. Time varying parameters: Chemicals.

exchange rates differ across countries and sectors, and over time. Exchange rates play a more important role, as indicated by the sub-sample estimates based on the identified structural breaks. As for oil prices, they have a positive effect on the energy sector in all countries, apart from India; a negative one on the financial sector in Brazil, China, India, South Africa, and Turkey; a negative one on the transportation sector in China, India, Turkey, and South Africa. In Russia, the sign of oil price parameters in the financial and transportation sectors varies over time. Thus, our analysis does not find any major differences between oil importers or exporters in the response of sectoral stock returns to oil price changes, consistently with the results of Filis et al. (2011).

Finally, the findings indicate that global events like the 2008 global financial crisis and the current COVID-19 pandemic tend to amplify the effects of oil prices and exchange rates on stock returns, particularly for sectors that depend heavily on energy, as these are particularly vulnerable to the risks associated with changes in global market conditions.

Data availability

Data will be made available on request.

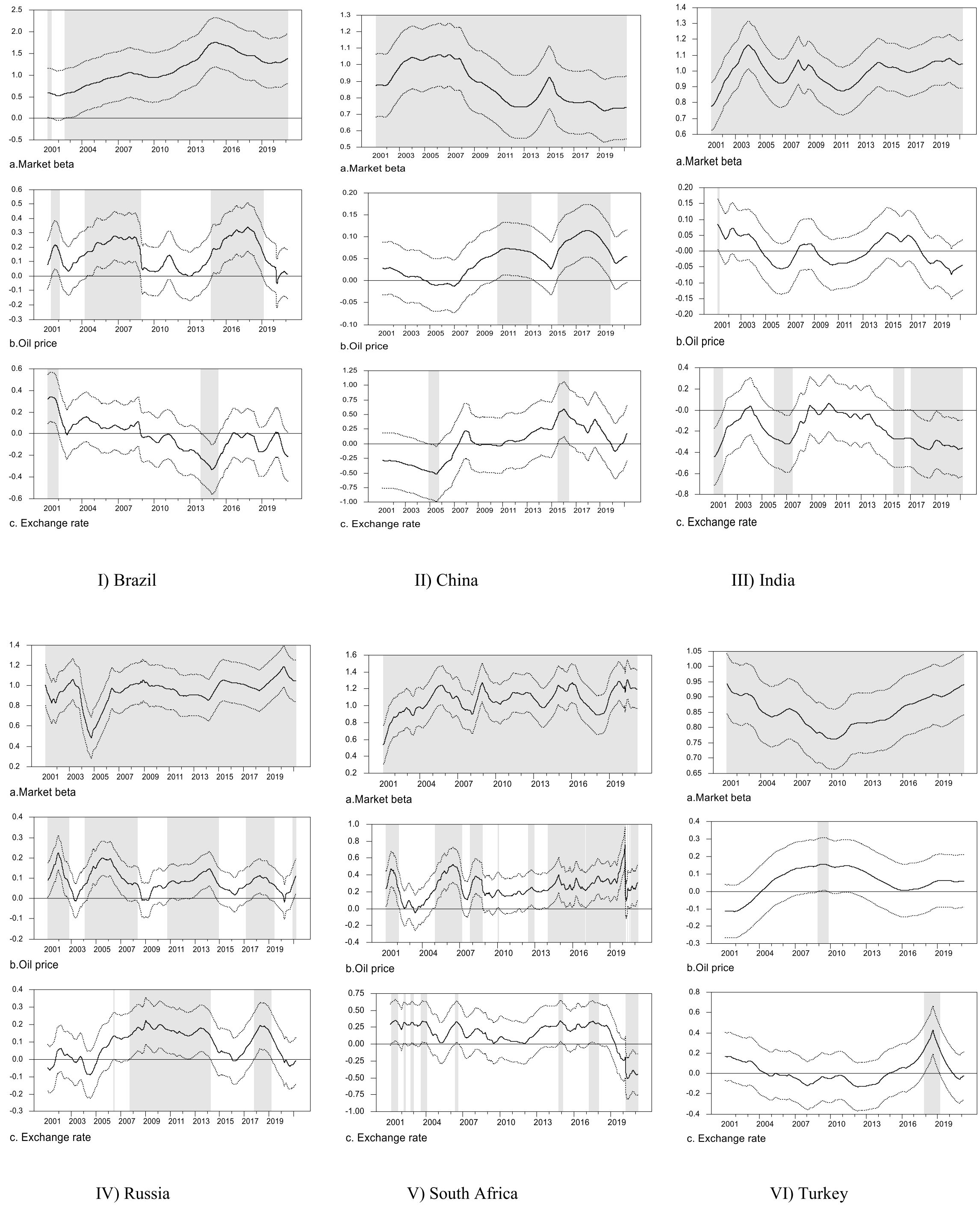


Figure 2. Time varying parameters: Energy.

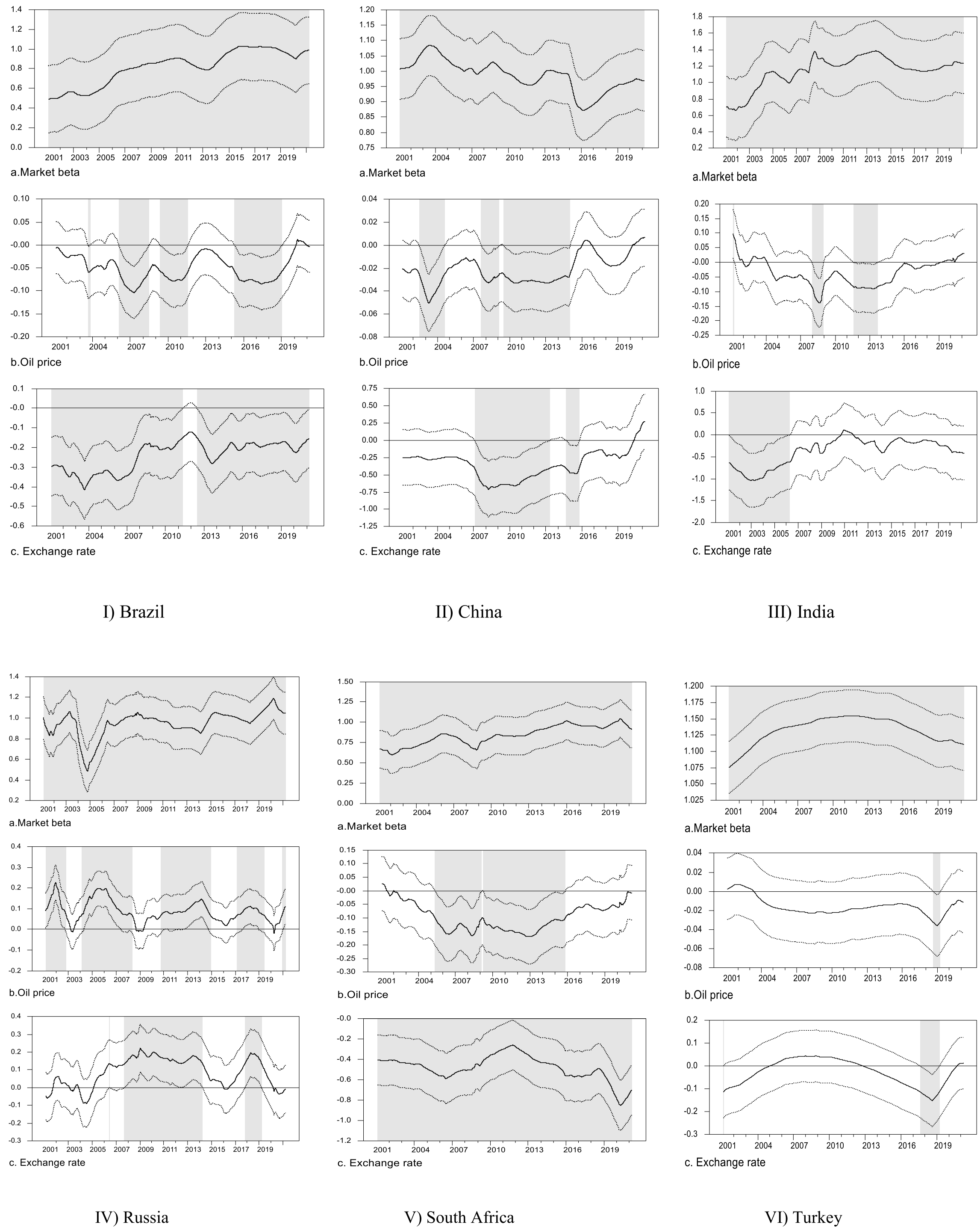
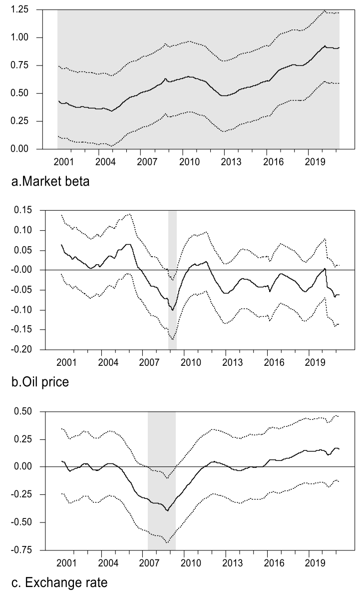
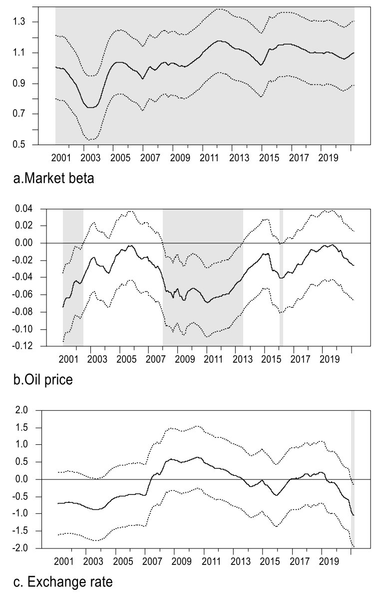


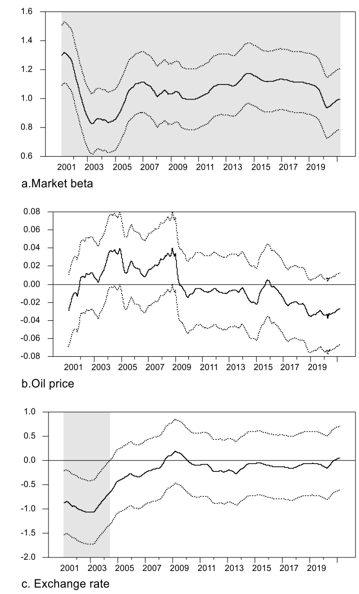
Figure 3. Time varying parameters: Financial.



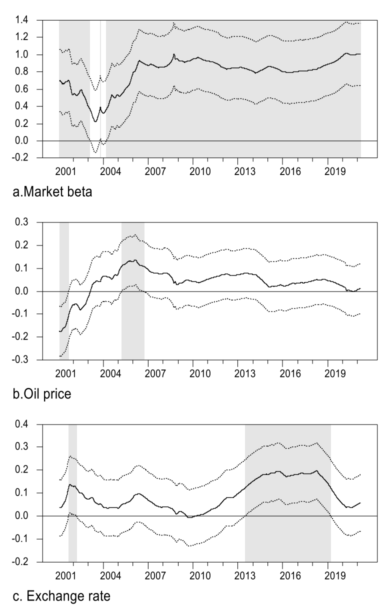
I) Brazil



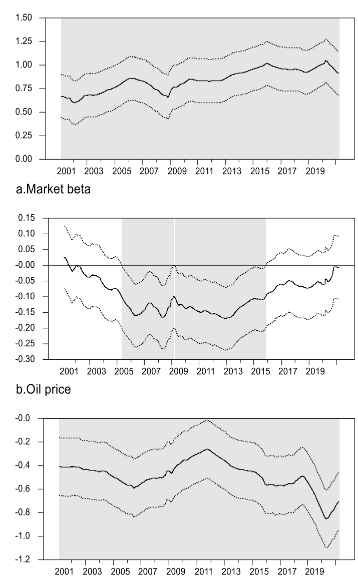
II) China



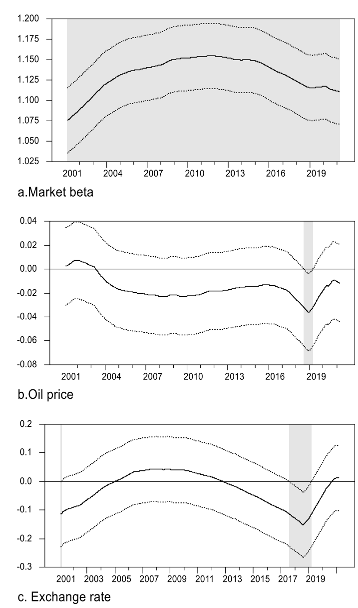
III) India



IV) Russia



V) South Africa



VI) Turkey

Figure 4. Time varying parameters: Industrials.

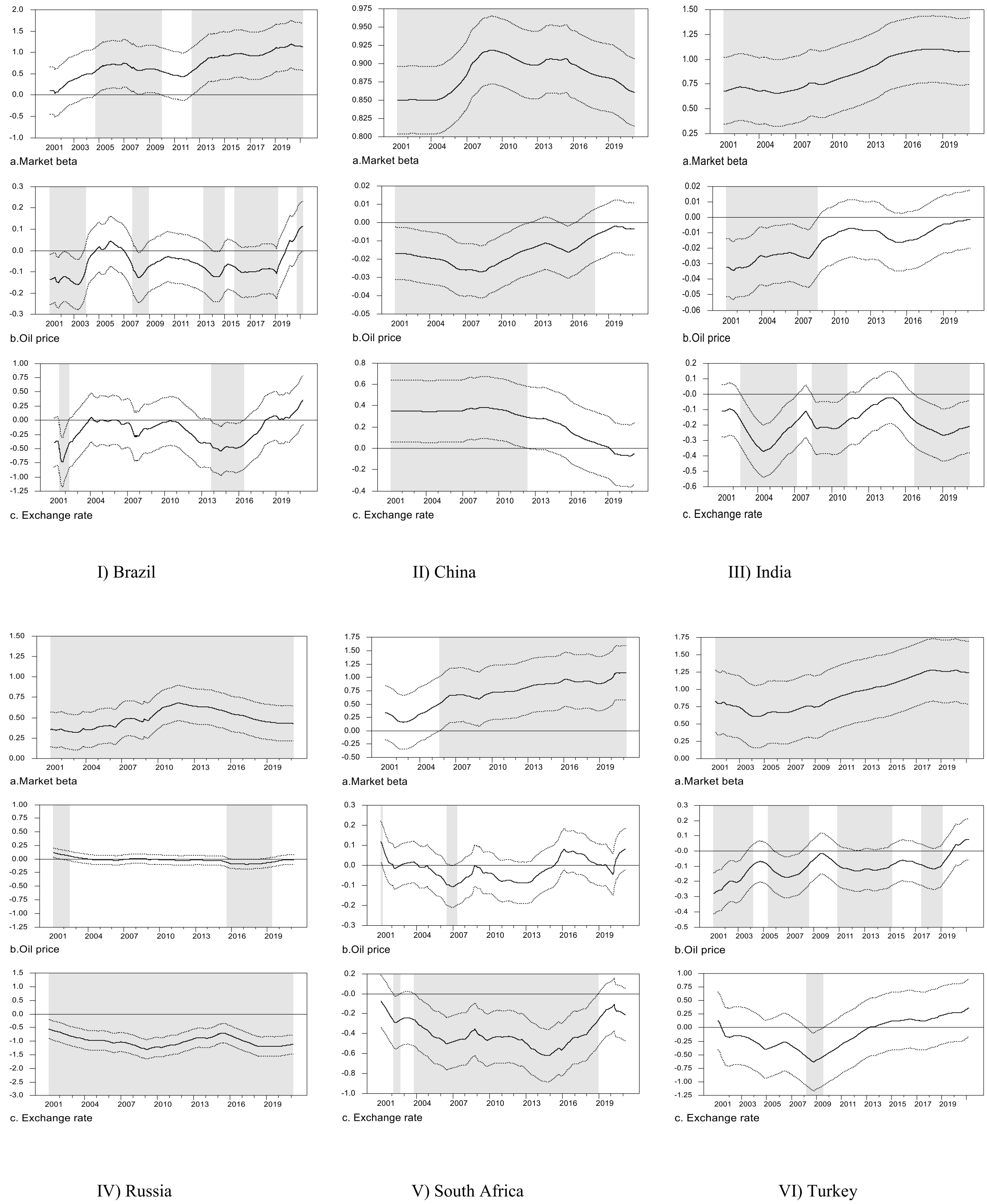


Figure 5. Time varying parameters: Transportation.

Table 4
Descriptive statistics for the time-varying parameters.

Sectors	Countries									
	Brazil					China				
		Mean	SE.	Min	Max		Mean	SE.	Min	Max
Chemical	$\beta_{im.t}$	0.825	0.164	0.117	1.595	$\beta_{im.t}$	1.047	0.131	0.761	1.300
	$\beta_{ioil.t}$	−0.008	0.099	−0.417	0.284	$\beta_{ioil.t}$	0.020	0.032	−0.064	0.079
	$\beta_{ier.t}$	−1.443	0.806	−3.210	−0.508	$\beta_{ier.t}$	0.391	0.770	−2.928	1.716
		Mean	**SE.**	**Min**	**Max**		**Mean**	**SE.**	**Min**	**Max**
Energy	$\beta_{im.t}$	1.125	0.347	0.526	1.760	$\beta_{im.t}$	0.871	0.116	0.721	1.061
	$\beta_{ioil.t}$	0.151	0.102	−0.053	0.340	$\beta_{ioil.t}$	0.047	0.036	−0.013	0.114
	$\beta_{ier.t}$	−0.023	0.138	−0.332	0.342	$\beta_{ier.t}$	0.005	0.287	−0.521	0.595
		Mean	**SE.**	**Min**	**Max**		**Mean**	**SE.**	**Min**	**Max**
Financial	$\beta_{im.t}$	0.817	0.171	0.483	1.030	$\beta_{im.t}$	0.985	0.049	0.873	1.083
	$\beta_{ioil.t}$	−0.049	0.028	−0.104	0.012	$\beta_{ioil.t}$	−0.021	0.012	−0.050	0.006
	$\beta_{ier.t}$	−0.241	0.075	−0.418	−0.121	$\beta_{ier.t}$	−0.347	0.201	−0.710	0.272
		Mean	**SE.**	**Min**	**Max**		**Mean**	**SE.**	**Min**	**Max**
Industrial	$\beta_{im.t}$	0.575	0.158	0.342	0.928	$\beta_{im.t}$	1.040	0.104	0.741	1.178
	$\beta_{ioil.t}$	−0.014	0.037	−0.100	0.066	$\beta_{ioil.t}$	−0.033	0.020	−0.074	−0.002
	$\beta_{ier.t}$	−0.033	0.145	−0.391	0.173	$\beta_{ier.t}$	−0.136	0.450	−1.049	0.637
		Mean	**SE.**	**Min**	**Max**		**Mean**	**SE.**	**Min**	**Max**
Transportation	$\beta_{im.t}$	0.703	0.278	0.042	1.192	$\beta_{im.t}$	0.884	0.023	0.849	0.918
	$\beta_{ioil.t}$	−0.062	0.059	−0.160	0.113	$\beta_{ioil.t}$	−0.016	0.007	−0.027	−0.002
	$\beta_{ier.t}$	−0.181	0.215	−0.739	0.355	$\beta_{ier.t}$	0.246	0.145	−0.076	0.382
Sectors	Countries									
	India					Russia				
		Mean	SE.	Min	Max		Mean	SE.	Min	Max
Chemical	$\beta_{im.t}$	0.774	0.188	−0.730	1.157	$\beta_{im.t}$	0.301	0.210	−0.003	0.717
	$\beta_{ioil.t}$	0.003	0.030	−0.077	0.075	$\beta_{ioil.t}$	0.003	0.085	−0.216	0.121
	$\beta_{ier.t}$	−0.220	0.368	−2.229	0.301	$\beta_{ier.t}$	−0.686	0.368	−1.304	−0.194
		Mean	**SE.**	**Min**	**Max**		**Mean**	**SE.**	**Min**	**Max**
Energy	$\beta_{im.t}$	0.994	0.076	0.773	1.164	$\beta_{im.t}$	0.948	0.123	0.485	1.188
	$\beta_{ioil.t}$	−0.001	0.040	−0.074	0.084	$\beta_{ioil.t}$	0.086	0.051	−0.018	0.227
	$\beta_{ier.t}$	−0.180	0.135	−0.444	0.063	$\beta_{ier.t}$	0.087	0.081	−0.090	0.224
		Mean	**SE.**	**Min**	**Max**		**Mean**	**SE.**	**Min**	**Max**
Financial	$\beta_{im.t}$	1.140	0.184	0.662	1.384	$\beta_{im.t}$	0.931	0.177	0.463	1.215
	$\beta_{ioil.t}$	−0.036	0.042	−0.139	0.098	$\beta_{ioil.t}$	−0.074	0.079	−0.225	0.102
	$\beta_{ier.t}$	−0.375	0.308	−1.039	0.112	$\beta_{ier.t}$	−0.215	0.302	−0.777	0.302
		Mean	**SE.**	**Min**	**Max**		**Mean**	**SE.**	**Min**	**Max**
Industrial	$\beta_{im.t}$	1.053	0.105	0.825	1.316	$\beta_{im.t}$	0.789	0.181	0.226	1.019
	$\beta_{ioil.t}$	−0.002	0.020	−0.037	0.040	$\beta_{ioil.t}$	0.041	0.054	−0.176	0.137
	$\beta_{ier.t}$	−0.275	0.329	−1.077	0.191	$\beta_{ier.t}$	0.090	0.061	−0.007	0.198
		Mean	**SE.**	**Min**	**Max**		**Mean**	**SE.**	**Min**	**Max**
Transportation	$\beta_{im.t}$	0.869	0.169	0.657	1.101	$\beta_{im.t}$	0.490	0.108	0.320	0.681
	$\beta_{ioil.t}$	−0.016	0.009	−0.034	−0.001	$\beta_{ioil.t}$	−0.020	0.043	−0.096	0.120
	$\beta_{ier.t}$	−0.187	0.084	−0.369	−0.022	$\beta_{ier.t}$	−1.003	0.178	−1.299	−0.550
Sectors	Countries									
	South Africa					Turkey				
		Mean	SE.	Min	Max		Mean	SE.	Min	Max
Chemical	$\beta_{im.t}$	0.516	0.272	0.225	1.043	$\beta_{im.t}$	0.767	0.049	0.689	0.888
	$\beta_{ioil.t}$	0.099	0.113	−0.059	0.330	$\beta_{ioil.t}$	0.002	0.064	−0.130	0.088
	$\beta_{ier.t}$	0.032	0.169	−0.326	0.363	$\beta_{ier.t}$	−0.126	0.337	−0.581	0.373
		Mean	**SE.**	**Min**	**Max**		**Mean**	**SE.**	**Min**	**Max**
Energy	$\beta_{im.t}$	1.066	0.139	0.517	1.312	$\beta_{im.t}$	0.852	0.049	0.762	0.945
	$\beta_{ioil.t}$	0.254	0.126	−0.047	0.761	$\beta_{ioil.t}$	0.058	0.076	−0.115	0.157
	$\beta_{ier.t}$	0.151	0.185	−0.509	0.356	$\beta_{ier.t}$	0.024	0.118	−0.131	0.432
		Mean	**SE.**	**Min**	**Max**		**Mean**	**SE.**	**Min**	**Max**
Financial	$\beta_{im.t}$	0.841	0.116	0.601	1.047	$\beta_{im.t}$	1.132	0.020	1.076	1.155
	$\beta_{ioil.t}$	−0.095	0.050	−0.169	0.026	$\beta_{ioil.t}$	−0.016	0.009	−0.036	0.007
	$\beta_{ier.t}$	−0.484	0.123	−0.851	−0.262	$\beta_{ier.t}$	−0.028	0.057	−0.153	0.044
		Mean	**SE.**	**Min**	**Max**		**Mean**	**SE.**	**Min**	**Max**
Industrial	$\beta_{im.t}$	0.749	0.123	0.555	0.932	$\beta_{im.t}$	0.757	0.105	0.614	1.001
	$\beta_{ioil.t}$	−0.039	0.037	−0.116	0.064	$\beta_{ioil.t}$	0.025	0.044	−0.086	0.131
	$\beta_{ier.t}$	−0.354	0.128	−0.687	−0.187	$\beta_{ier.t}$	0.003	0.256	−0.369	0.394
		Mean	**SE.**	**Min**	**Max**		**Mean**	**SE.**	**Min**	**Max**
Transportation	$\beta_{im.t}$	0.695	0.254	0.161	1.092	$\beta_{im.t}$	0.933	0.225	0.608	1.281
	$\beta_{ioil.t}$	−0.017	0.052	−0.105	0.119	$\beta_{ioil.t}$	−0.104	0.067	−0.279	0.076
	$\beta_{ier.t}$	−0.392	0.131	−0.620	−0.074	$\beta_{ier.t}$	−0.115	0.268	−0.634	0.364

Note: This table presents the descriptive statistics of the time-varying coefficients estimated from the state-space model at sectoral level.

Appendix

Table A1
Data Sources and Description

Countries Variables	Brazil	China	India	Russia	South Africa	Turkey
Sectoral stock index	-DS	-DS	-DS	-DS -Red Star Financials -FTSE	-DS -FTSE	-DS -BIST
Exchange rate	Brazilian real to US dollar	Chinese yuan to US dollar	Indian rupee to US dollar	Russian rouble to US dollar	South Africa rand to US dollar	New Turkish lira to US dollar
Benchmark Stock index	Brazil Bovespa	Shanghai stock exchange	Nifty 500	Moex Russia	FTSE/JSE all share	BIST national 100
Oil price	Europe Brent Spot Price Free on Board (Dollars Per Barrel)	Europe Brent Spot Price Free on Board (Dollars Per Barrel)	Europe Brent Spot Price Free on Board (Dollars Per Barrel)	Europe Brent Spot Price Free on Board (Dollars Per Barrel)	Europe Brent Spot Price Free on Board (Dollars Per Barrel)	Europe Brent Spot Price Free on Board (Dollars Per Barrel)
Interest rate	Interbank deposit certification rate	The 3-month deposit rate	The 1-month deposit rate	The 3-month deposit rate	The 1-month deposit rate	The 1-month deposit interest rate

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