

Tok, Şerife Akıncı; Tarkun, Savaş

Article

Dynamic dependence between sectoral indexes of BRIC countries and the baltic dirty tanker index: An investigation using the generalized R2 approach

Borsa İstanbul Review

Provided in Cooperation with:

Borsa İstanbul Anonim Şirketi, İstanbul

Suggested Citation: Tok, Şerife Akıncı; Tarkun, Savaş (2025) : Dynamic dependence between sectoral indexes of BRIC countries and the baltic dirty tanker index: An investigation using the generalized R2 approach, Borsa İstanbul Review, ISSN 2214-8469, Elsevier, Amsterdam, Vol. 25, Iss. 2, pp. 265-274,
<https://doi.org/10.1016/j.bir.2025.01.010>

This Version is available at:

<https://hdl.handle.net/10419/340568>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by-nc-nd/4.0/>



Dynamic dependence between sectoral indexes of BRIC countries and the baltic dirty tanker index: An investigation using the generalized R2 approach

Şerife Akıncı Tok ^{a,*} , Savaş Tarkun ^b 

^a Faculty of Economics and Administrative Sciences, Zonguldak Bulent Ecevit University, Zonguldak, Türkiye

^b Faculty of Engineering and Natural Sciences, Bursa Technical University, Bursa, Türkiye

ARTICLE INFO

JEL classification:

C32

F14

G15

Keywords:

BDTI

BRIC countries

Freight prices

Generalized R^2

Volatility

ABSTRACT

This study analyzes the dynamic connectedness between the Baltic Dirty Tanker Index (BDTI) and sector indexes in the stock exchanges of the BRIC countries, focusing on the chemical, oil, and raw materials sectors. Using daily data from January 1, 2015, to September 30, 2024, the analysis reveals significant pairwise relationships, highlighting the sensitivity of these sector indexes to shipping costs. The findings indicate that during periods of heightened market volatility, the BDTI has substantial influence, especially on Russia's chemical and India's oil and gas sectors. These results suggest that geopolitical risks and market uncertainty can significantly amplify interdependence. Based on these insights, proactive policies aimed at stabilizing shipping costs and improving cooperation among the BRIC countries are recommended to mitigate the impact of unexpected increases in freight rates. This study offers valuable information for policy makers, investors, and industry representatives for strengthening risk management strategies in shipping and logistics.

1. Introduction

Global energy markets play a critical role worldwide, closely linking various sectors of the economy and trade (Asif & Muneer, 2007; Shahbaz et al., 2013; Zakeri et al., 2022). Fluctuation in these markets leads to significant changes in maritime transportation costs, which largely impact transportation and energy consumption (Dai et al., 2020). The Baltic Dirty Tanker Index (BDTI) is a widely used indicator that measures the relationship between maritime transportation costs and the energy sector. It offers valuable insights into the economic balance in the energy and trade sectors because of its sensitivity to volatility in energy prices (Choi & Yoon, 2020). The BDTI shows the sensitivity of maritime transportation costs to market shocks and geopolitical shifts, which directly affect the economic structure of countries that depend on energy imports and exports (Khan et al., 2021; Qi et al., 2023).

The BRIC countries (Brazil, Russia, India, and China) are noteworthy for having rapidly growing economies, with intensive activity in heavy industries, such as energy and chemicals. Their energy and chemical sectors play a critical role in shaping the world economy because of their supply-demand balances and import dependence. For example, Russia's chemical sector (MOEX Chemicals index) and India's oil and gas sector

(S&P BSE Oil & Gas index) are highly sensitive to fluctuation in energy markets, and cost pressures in these sectors are directly reflected in maritime transportation indexes. China's SSEMT Materials index, however, directly affects the country's expenditures on imports expenditures to that meet its high demand for raw materials, through transportation costs (Benlagha et al., 2022; Billah et al., 2022; Wang et al., 2022).

Sector indexes traded on the stock exchanges of BRIC countries are tightly correlated with BDTI freight prices, especially in the energy and chemical sectors. For example, Russia's MOEX Chemicals index is highly correlated with the BDTI based on the sensitivity of the country's chemical sector to energy prices. Fluctuation in energy prices causes volatility, especially in Russia's chemical index, increasing the pressure on the BDTI. Similarly, India's S&P BSE Oil & Gas index strongly interacts with the BDTI because of the country's dependence on energy imports. India's additional cost pressure on transportation costs during periods of rising energy prices further increases the correlation of the S&P BSE index with the BDTI.

At the same time, China's SSEMT Materials index is closely correlated with the country's global demand for raw materials. It exerts upward pressure on BDTI freight prices during periods of rising production demand. China's production and import expenditures directly affect

* Corresponding author.

E-mail addresses: s.akinci@beun.edu.tr (Ş. Akıncı Tok), savastarkun@gmail.com (S. Tarkun).

<https://doi.org/10.1016/j.bir.2025.01.010>

Received 31 October 2024; Received in revised form 9 January 2025; Accepted 10 January 2025

Available online 11 January 2025

2214-8450/Copyright © 2025 Borsa İstanbul Anonim Şirketi. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

maritime transportation costs by strengthening its linkages with the BDTI. These linkages are also confirmed by the generalized R^2 dependence method applied by Balli et al. (2023), which reveals the extent to which maritime transport costs are sensitive to changes in energy and raw material markets through the sector indexes of BRIC countries.

This study explores some key research questions by examining the relationship between the energy and chemical sector indexes of the BRIC countries and the BDTI. First, it clarifies the level of aggregate connectedness between the BRIC countries' sector indexes and the BDTI and its changes over time. The study also looks at directional interactions between the BDTI and the BRIC indexes and identifies which indexes have larger impacts on the others. It also determines whether interaction between the BRIC indexes and the BDTI significantly increases, especially during crisis periods when energy prices fluctuate. Finally, it examines the extent to which energy costs in energy-intensive countries, such as China, India, and Russia, increase the directional and aggregate effects on the BDTI and assesses the implications of these interactions for global trade and transportation costs.

Imbalances in global trade and energy markets have a direct impact on energy and transportation costs, increasing the sensitivity to these costs of emerging economies, such as the BRICs. Understanding the linkages between the chemical and energy indexes of the BDTI and BRIC countries is crucial for managing the pressure of energy price fluctuations on international transportation costs. The goal of this study is to reveal the dynamic nature of the interactions between these sectors and to analyze the responses of shipping costs to global energy supply and demand during periods of energy crises and other economic shocks. The study offers policy makers and industry representatives strategic insights that they can employ in better management of the impact of energy market fluctuations on transportation costs. In particular, demonstrating the sensitivity of ocean transportation costs to rising energy prices highlights the need to develop strategic solutions in order to ensure the sustainability of international trade.

Although the literature on energy-finance interactions and sectoral dependence is extensive, significant gaps remain in explaining the dynamic and directional relationships between energy transportation costs and sectoral indexes. Previous studies have largely focused on traditional spillover models or static dependence frameworks, overlooking the potential of advanced methodologies to capture simultaneous and lagged effects.

This study makes a significant contribution by applying the generalized R^2 decomposition methodology to analyze sectoral dependence between the BDTI and the chemical, oil/gas, and raw materials sectoral indexes in the BRIC countries. By employing this innovative approach, the study addresses a critical gap in explaining the evolution in sectoral dependence over time and during crises. Furthermore, it extends the existing literature by providing empirical evidence on how energy transportation costs amplify sectoral vulnerability in emerging markets, particularly in the presence of geopolitical risks and market uncertainty.

Our findings offer a nuanced understanding of sectoral interconnections and provide actionable insights for policy makers, investors, and industry stakeholders. This study thus advances the theoretical and methodological frontiers of energy-finance research.

After this introduction, the paper is organized as follows. We review the relevant literature on in Section 2. Then, in Section 3, we present the theoretical framework of the study and, in Section 4, the data. Section 5 presents the empirical findings. Section 6 gives a discussion in light of the findings. Section 7 outlines our conclusions, implications and recommendations.

2. Literature review

The linkages between energy and financial markets are critical for investors and policy makers. Understanding the impact of energy price changes and transportation costs on stock markets is an essential area of research, especially in energy cost-sensitive sectors. Many studies have

analyzed the spillover effects of oil price shocks and energy market uncertainty on financial markets, showing changes in these interactions over time (Jones & Kaul, 1996; Sadorsky, 1999). These studies emphasize that volatility in energy markets becomes an increasing risk factor in financial markets during crisis periods. Understanding the impact of indexes representing energy transportation costs, such as the BDTI, on sectoral indexes is critical for a more detailed understanding of the relationship between energy uncertainty and stock markets.

Over time, the models used to analyze this relationship between energy prices and stock markets have also diversified. Diebold and Yilmaz (2012) developed the spillover index as a groundbreaking methodological advancement in analyzing financial market linkages. This model enables a clearer observation of risk transmission across markets. Expanding on this, Baruník and Křehlík (2018) use a time-frequency perspective to analyze spillover effects, observing that these effects intensify during crises.

The decomposition method and copula approach used by Choi and Yoon (2020) examine the impact of crude oil prices on the shipping market using the Baltic Dry Index (BDI), BDTI, and Baltic Clean Tanker Index (BCTI), which reveal the time-varying asymmetry in dependence structures. Similarly, Dai et al. (2020) apply the BEKK-GARCH model to Brent oil prices and the BDTI, demonstrating that volatility is transmitted from the crude oil market to the tanker market in the long run. These findings emphasize the need for tailored strategies during financial crises.

2.1. Methodological innovations and sectoral dynamics

Recent studies have employed more nuanced methodologies to explore the dynamic interconnections between financial and energy markets. Balli et al. (2023) introduce the generalized R^2 decomposition method, which offers an innovative approach for examining simultaneous and lagged spillovers in energy futures markets. This method has proved particularly effective in clarifying sectoral dependence and its evolution. Dang et al. (2024) apply a quantile time-frequency connectedness approach to explore sectoral uncertainty spillovers in emerging markets, highlighting the importance of methodological advancements for revealing hidden dynamics.

Sector-specific studies also illustrate diverse interdependence. For example, Aslam et al. (2023) examine equity sectors in Pakistan, showing strong directional dependence between energy and other critical sectors. Shahzad and Naifar (2022) further analyze dependence dynamics during the COVID-19 pandemic, demonstrating heightened sectoral vulnerability in crisis periods.

Kapar et al. (2024) investigate the frequency dynamics of spillovers among Gulf Cooperation Council (GCC) sectoral indexes, identifying regime-dependent spillovers that intensify during geopolitical crises. These findings align with those by Balli et al. (2013), who analyze sectoral equity returns, highlighting time-varying spillover effects that become more pronounced during periods of economic volatility.

2.2. Sectoral dependence in emerging markets

Emerging markets, particularly the BRIC countries, have unique sectoral dependence driven by their economic structures and energy needs. Dang et al. (2023) analyze ten sectors in emerging markets, identifying significant time-frequency variations in sectoral dependence. Russia's chemical sector and India's oil and gas sector are susceptible to global energy price fluctuations, reflecting their structural reliance on energy imports and production. Similarly, Hedström et al. (2019) demonstrate that regional crises intensify financial contagion risks in emerging economies, emphasizing the need for a detailed understanding of sectoral dependence.

China's demand for raw materials creates a strong linkage between the SSEMT Materials Index and the BDTI, whereas India's dependence on energy imports intensifies the relationship between the S&P BSE Oil

& Gas Index and global transportation costs (Cui et al., 2021; Mobarek et al., 2016). These studies highlight the critical role of sectoral characteristics in shaping market responses to global energy dynamics.

2.3. The role of geopolitical risks and crises

Geopolitical risks and crises significantly affect energy and financial markets, often amplifying sectoral spillovers. Yousaf et al. (2022) explore the impact of geopolitical risks on GCC equity markets, demonstrating substantial asymmetric spillovers during volatile periods. Kapar et al. (2024) further highlighted that sectoral spillovers in GCC countries intensify during geopolitical crises, and energy-intensive sectors have the strongest dependence. The Energy-Linked Uncertainty Index (EUI) developed by Dang et al. (2023) provides a new approach for analyzing the impact of energy uncertainty on financial market volatility. The index captures energy price shocks, political risks, and supply-demand imbalances and is used to capture the impact of energy market uncertainty on sectoral indexes. Since the development of the EUI, the interactions between energy uncertainty and financial markets has become more pronounced and the spillover effects have increased during crisis periods (Zhang & Guo, 2024).

COVID-19 is a unique context for exploring interdependence. Guo et al. (2021) analyze tail risk contagion during the pandemic, observing increased spillovers among international financial markets. Shahzad and Naifar (2022) show that the pandemic strengthened existing dependence and reveal new risk transmission channels between Islamic and conventional equity sectors.

3. Theoretical framework

Maritime transportation is the backbone of global trade and is highly sensitive to fluctuation in energy prices. The BDTI is one of the main indexes that examine the relationship between maritime transport costs and energy markets, enabling analysis of changes in transportation costs for economies based on energy imports and exports. The theoretical underpinning of this study is the literature on the impact of fluctuation in energy markets on maritime transportation costs. Volatility in energy prices increases cost pressures, especially in the maritime transportation sector, which increases the risk factor for countries with high energy security and high import dependence. Accordingly, this paper provides a theoretical framework on the way in which BDTI responses to energy prices are shaped by intersectoral linkages.

The BRIC countries are key actors in the global economy based on their close ties to energy markets as well as their production and trade capacity. The industrial and energy sectors of Brazil, Russia, India, and China have a direct impact on the global energy supply-demand balance through their relationship with the BDTI, and energy costs are reflected in the maritime transportation sector in different ways. For instance, India's dependence on oil imports increases the impact of global energy price increases on transportation costs, whereas China's production and raw material demand creates a strong correlation between raw material transportation costs and the BDTI. Russia's energy production capacity and production costs in the chemicals sector are also sensitive to energy price volatility and strongly interact with the BDTI. In this framework, analyzing the relationship between the sectoral indexes of BRIC countries and the BDTI provides a critical theoretical background for understanding the effects of global energy price fluctuations on the maritime transport sector.

The generalized R^2 connectedness approach by Balli et al. (2023) used in this study is based on a theoretical background that examines changes in sectoral interactions over time. By measuring the interactions between the BRIC sector indexes and the BDTI, this method provides a more dynamic understanding of the structure of intersectoral connectedness. The theoretical framework of connectedness analysis is based on the theory of market linkages, which predicts the strengthening of intersectoral connectedness in times of crisis, when energy prices rise. In

this context, the theoretical framework of the study provides a basis for understanding the impact of global energy crises on maritime transportation costs by considering the effects of energy and chemical sector indexes of the BRIC countries on the BDTI from a time-dependent connectedness perspective.

4. Data

This study uses the generalized R^2 connectedness approach to analyze the dynamic relationship between the BDTI and the chemical, oil/gas, and commodity indexes of the BRIC countries. This method was chosen for its ability to assess the time-varying sectoral dependence structure and to examine how these interactions are shaped during crisis periods.

4.1. Data sample

Our data sample consists of a logarithmic return series calculated over daily closing prices. Closing prices of sectoral indexes of the BDTI and BRIC countries are obtained for the period January 2015–September 2024. The following indexes are used.

- BDTI (Baltic Dirty Tanker Index): Used as a proxy for global energy transportation costs
- BRIC Countries Sectoral Indexes: Brazil IMAT (Raw Materials Index), Russia MOEX (Chemicals Index), India S&P BSE (Oil and Gas Index), and China SSEMT (Materials Index).

Fig. 1 shows the logarithmic return series for the BRIC and BDTI sector indexes. These series are calculated based on daily closing prices between January 2015 and September 2024. The figure clearly shows the fluctuations in the indexes over time and the trends in volatility. In particular, sudden price changes are observed during periods of high demand for energy and commodities, and these changes increase sharply during periods of crisis. Overall, this figure illustrates the interdependence between shipping and sector indexes, showing that changes in energy costs affect the BRIC indexes.

Table 1 lists the summary statistics of the indexes, showing the structure of the returns of the BDTI and specific sectoral indexes of the BRIC countries (IMAT, MOEX, BSE, SSEMT). The average returns for the BDTI are negative, indicating its downward volatility, especially recently. However, the IMAT, MOEX, BSE, and SSEMT indexes have generally positive average returns, suggesting that these sectors are gaining momentum, in line with economic recovery or demand growth.

The skewness and excess kurtosis values in Table 1 reveal that the series deviates significantly from the normal distribution and is prone to volatility. In particular, the skewness (+3.5) and the excess kurtosis (+151.83) of the MOEX index are quite high, indicating that the market uncertainty in Russia's chemical sector is high, and the market is subject to sudden fluctuation. This is noteworthy for explaining the repercussions of geopolitical events in Russia and oil price fluctuations in the chemical sector.

4.2. Method: Balli et al. (2023) generalized R^2 connectedness approach

We use a VAR(p) model with time-series analysis to identify the dynamic connectedness between the sectoral indexes of the BDTI and the BRIC countries. This model enables the decomposition of simultaneous and lagged interactions across sectors. The model with the generalized R^2 approach is constructed as follows (Balli et al., 2023; Diebold & Yilmaz, 2012, 2014):

$$y_t = \sum_{i=1}^p B_i y_{t-i} + u_t \text{ and } u_t \sim N(0, \Sigma) \quad (1)$$

where y_t is the vector of log-returns of the connectedness indexes for

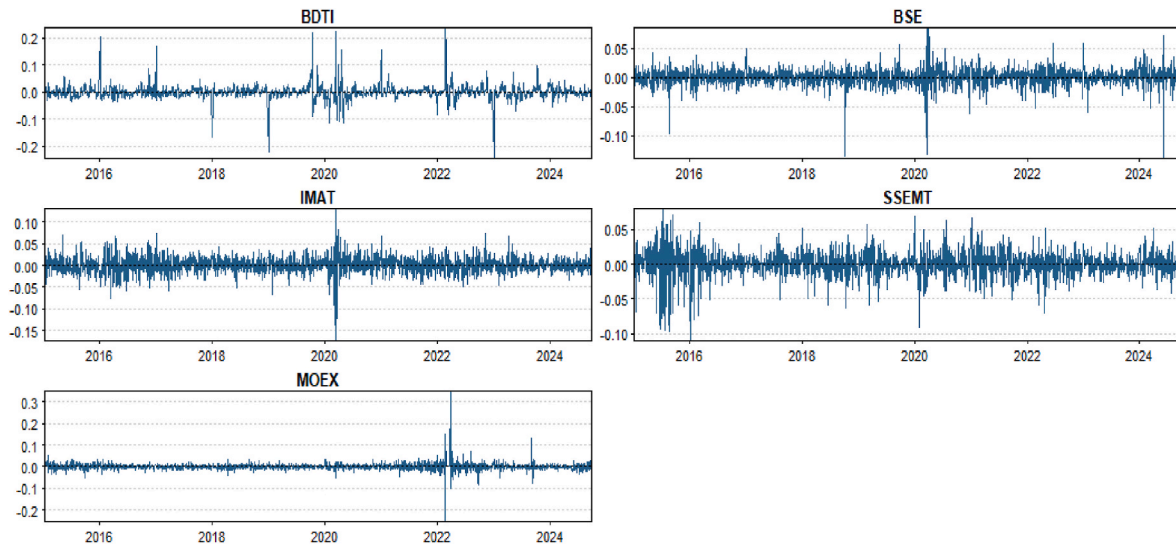


Fig. 1. Logarithmic return series for the BRIC and BDTI sector indexes.

Table 1
Summary statistics.

	BDTI	IMAT	MOEX	BSE	SSEM
Mean	-0.001 (0.983)	0.06 (0.103)	0.054* (0.086)	0.048* (0.098)	0.007 (0.836)
Variance	5.632	3.336	2.373	2.038	3.073
Skewness	1.379*** (0.000)	-0.540*** (0.000)	3.500*** (0.000)	-1.227*** (0.000)	-0.691*** (0.000)
Ex.Kurtosis	30.749*** (0.000)	8.559*** (0.000)	151.831*** (0.000)	14.305*** (0.000)	5.262*** (0.000)
JB	96,619.659*** (0.000)	7544.777*** (0.000)	2,341,931.751*** (0.000)	21,353.967*** (0.000)	3000.594*** (0.000)
ERS	-18.924 (0.000)	-5.692 (0.000)	-22.503 (0.000)	-20.513 (0.000)	-21.004 (0.000)
Q(20)	1307.218*** (0.000)	18.103** (0.000)	29.708*** (0.000)	24.639*** (0.000)	42.860*** (0.000)
Q ² (20)	352.769*** (0.000)	2093.426*** (0.000)	82.961*** (0.000)	303.852*** (0.000)	1236.965*** (0.000)

Notes: Skewness: D’Agostino (1970) test; Kurtosis: Anscombe and Glynn (1983) test; JB: Jarque and Bera (1980) normality test; ERS: Elliott et al. (1996) unit-root test; Q(20) and Q²(20): Fisher and Gallagher (2012) weighted Portmanteau test statistics. P values are in parentheses. Significance: * as 0.10, ** 0.05, and *** 0.01.

period t , B_i is the coefficient matrix of the sectoral connectedness across periods and shows the effect of each index on the other indexes, and u_t is the error term.

4.3. Rolling-window method

Our data sample has a window with a length of T and a width of w . For each w -wide subsample, we continue to roll the window, rebuild the model, and connected the compliance measures (Zhang et al., 2023). In this case:

The first window contains observations y_1, y_2, \dots, y_w .

The second window contains the observations y_2, y_3, \dots, y_{w+1} .

In this way, the last window covers the observations y_{T-w+1}, \dots, y_T .

For each rolling window, R^2 -based measures of connectedness are repeatedly calculated.

4.4. Connectedness and dynamic analysis

This study examines interindustry connectedness through the total and directional connectedness indicators. In this context, the Total Connectedness Index (TCI) is calculated using the generalized R^2 approach and explained using the following equation (Diebold & Yilmaz, 2012, 2014):

$$TCI = \frac{1}{K} \sum_{k=1}^K R_k^2 \tag{2}$$

This equation shows the extent to which the total variance of all indexes is explained by other indexes. Dynamic TCI is calculated using a sliding -window technique to capture time-varying connectedness.

4.5. Analysis of contemporaneous and lagged interactions

Using generalized R^2 decomposition, we calculate simultaneous and lagged interactions as follows (Baur & Hoang, 2021):

$$R_{xx} = VAV' = CC' \tag{3}$$

This analysis is important for decomposing the lagged and contemporaneous effects of crisis-related energy price fluctuations on sectoral indexes, and the results are evaluated from a time-varying perspective.

4.6. Connectedness measurements

We use these methods to analyze the relationships between energy and transportation costs in a way that reveals the connectedness shifts that are especially evident during crisis periods.

- Net Total Directional Connectedness: Measures the degree to which a particular index has a directional effect on other indexes
- Pairwise Connectedness: Assesses the degree of pairwise effects between the sectoral indexes of the BRIC countries and the BDTI.

5. Empirical findings

Connectedness analysis analyzes the total and directional effects between indexes over time. These analyses reveal changes in market relationships over time and help to identify which indexes are more influential than others during periods of crisis or shocks.

Fig. 2 shows changes in the aggregate dynamic connectedness (in red) between global energy and shipping markets (in black and green). The regions in black represent periods of high connectedness and coincide with global shocks, such as energy crises. During these periods, energy prices fluctuate sharply, transportation costs are highly responsive to these changes, and intersectoral connectedness increases sharply. The high connectedness of the black regions indicates that the relationship between energy and transportation markets reaches critical levels during crisis periods, and prices quickly spill over to other sectors. In contrast, green regions reflect periods when market conditions are more stable, energy prices are relatively stable, and intersectoral linkages are low. These green regions indicate that, under normal economic conditions, energy fluctuations have a limited impact on maritime transportation costs. The red line represents a critical threshold of dynamic aggregate connectedness; crossing this line indicates that the interaction between energy and transportation markets is at its highest, so price shocks are strongly transmitted to transportation costs. Overall, Fig. 1 illustrates the different dynamics during periods of crisis and stability, showing increases in the impact of energy prices on maritime transportation costs, especially during shocks, and crosses the red line.

Fig. 3 shows the changes over time in the directional connectedness between the BDTI and specific sector indexes of the BRIC countries. These indexes—Russia’s MOEX Chemicals, India’s S&P BSE Oil & Gas, China’s SSEMT Materials, and Brazil’s IMAT Raw Materials—capture the extent to which energy, chemicals, and raw materials sectors influence global transportation costs. During periods of high net connectedness, price fluctuations in these indexes, particularly in the energy and raw materials sectors, exert strong pressure on the BDTI, leading to significant increases in maritime transportation costs. For example, Russia’s MOEX Chemicals index has a direct impact on the BDTI during periods of high energy price volatility, whereas India’s S&P BSE Oil & Gas index exerts directional pressure on these costs due to its dependence on energy imports. In contrast, periods of lower or stable

directional interaction in the figure indicate periods when the impact of price fluctuations in the energy and raw materials sectors on the BDTI is limited, and global transportation costs remain more stable. Fig. 3 thus illustrates that the effects of the BRICs’ sectoral indexes on the BDTI are intensified during crisis periods, and transportation costs become more sensitive to index fluctuations during these periods.

Fig. 4 shows the changes in interactions driven by BDTI on the BRIC countries’ sector indexes over time. These indexes—Russia’s MOEX Chemicals, India’s S&P BSE Oil & Gas, China’s SSEMT Materials, and Brazil’s IMAT Raw Materials—demonstrate that the BDTI has had an impact on the energy, chemicals, and raw materials sectors, depending on transportation costs. The figure illustrates that the impact of the BDTI on these indexes increases during periods of high volatility in global energy prices. This reflects that changes in maritime transportation costs, in particular, put intense pressure on economies such as India and China, which are dependent on energy and raw materials imports.

The high impact of the BDTI on the Indian S&P BSE Oil & Gas index indicates periods when increases in energy import costs are directly reflected in transportation costs. Likewise, China’s demand for raw materials is sensitive to fluctuations in maritime transportation costs, amplifying the impact of the BDTI on China’s SSEMT Materials index. The figure shows that the steering power of the BDTI on other indexes increases significantly during crisis periods, when the repercussions of transportation costs and market fluctuations on BRIC countries become stronger.

Fig. 5 shows the directional impact of the BDTI on the sectoral indexes of the BRIC countries. The impact of the BDTI on sectoral indexes regarding fluctuation in energy prices can be assessed by looking at this figure. Overall, the BDTI affects the energy and chemical sector indexes in BRIC countries to different degrees, suggesting that the sensitivity of the indexes to energy prices varies depending on sectoral and geographic characteristics. In particular, India’s S&P BSE Oil & Gas index and China’s SSEMT Materials index are highly affected by the BDTI, reflecting the economic structure of these countries, such as energy import dependence and demand for raw materials. India’s dependence on oil imports increases its sensitivity to fluctuation in energy prices, which leads to a direct impact of price changes in the BDTI on the S&P BSE Oil & Gas index. Similarly, China’s SSEMT Materials index is also sensitive to fluctuation in the BDTI due to the country’s intensive production and demand for imports of raw materials; during periods of increase in the BDTI, China’s production costs rise, directly affecting maritime transportation costs.

However, the BDTI strongly influences Russia’s MOEX Chemicals index. Russia’s position in energy markets creates high volatility in the

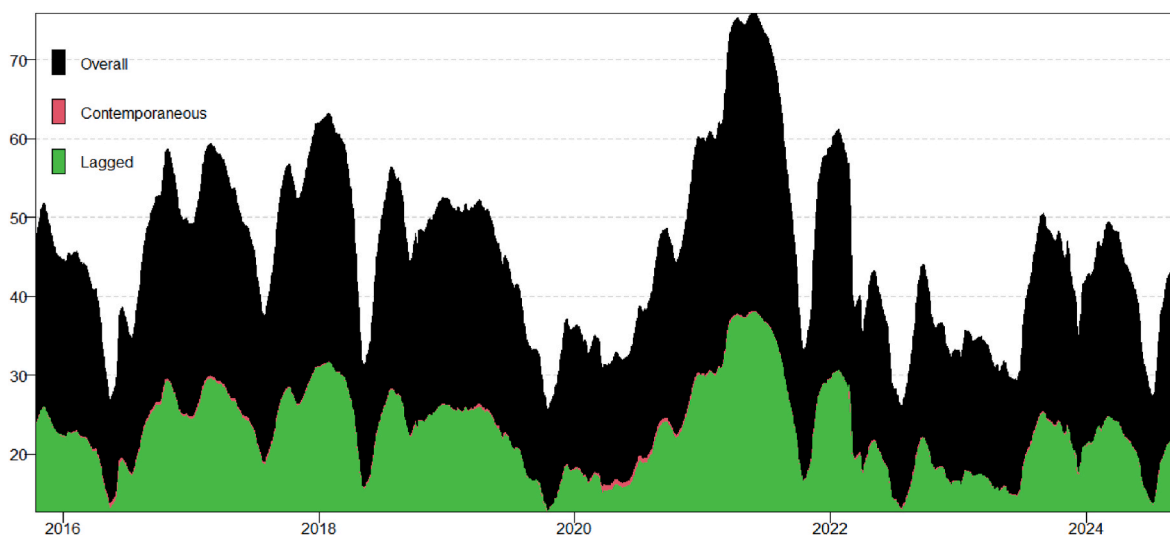


Fig. 2. Dynamic total connectedness.

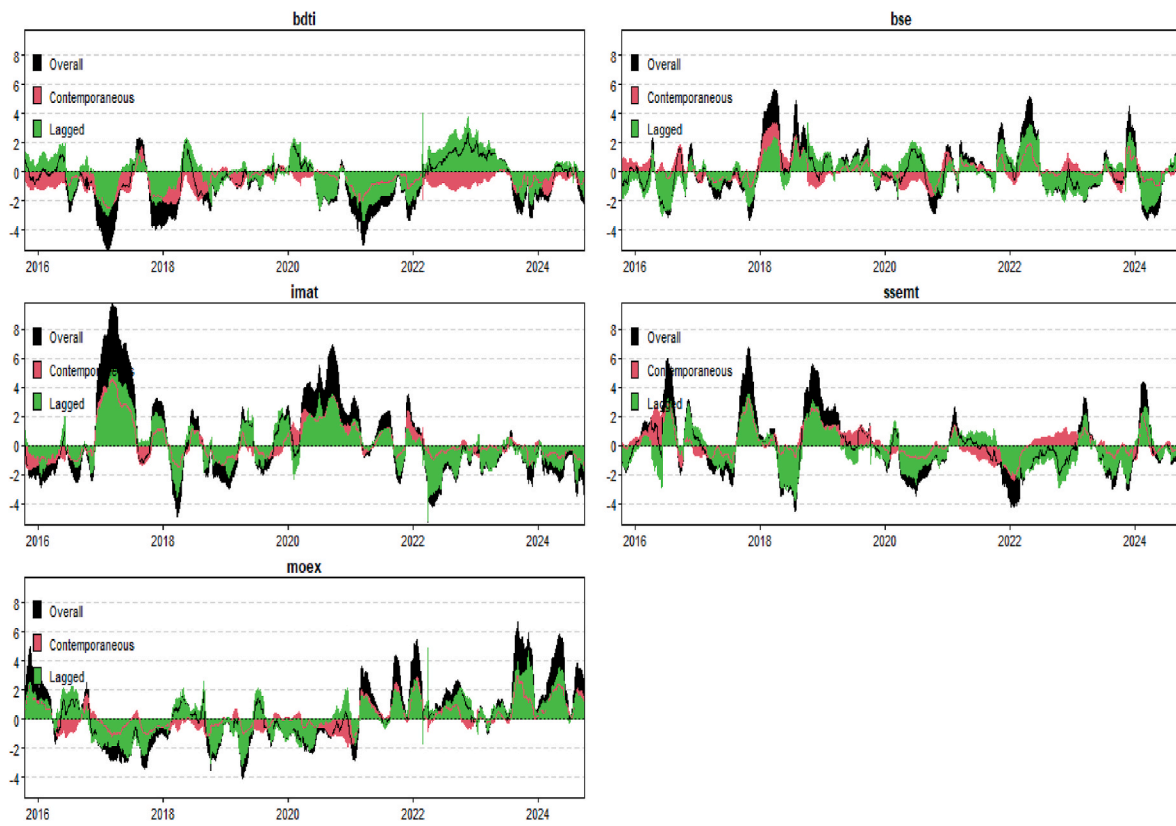


Fig. 3. Net total directional connectedness (TDC).

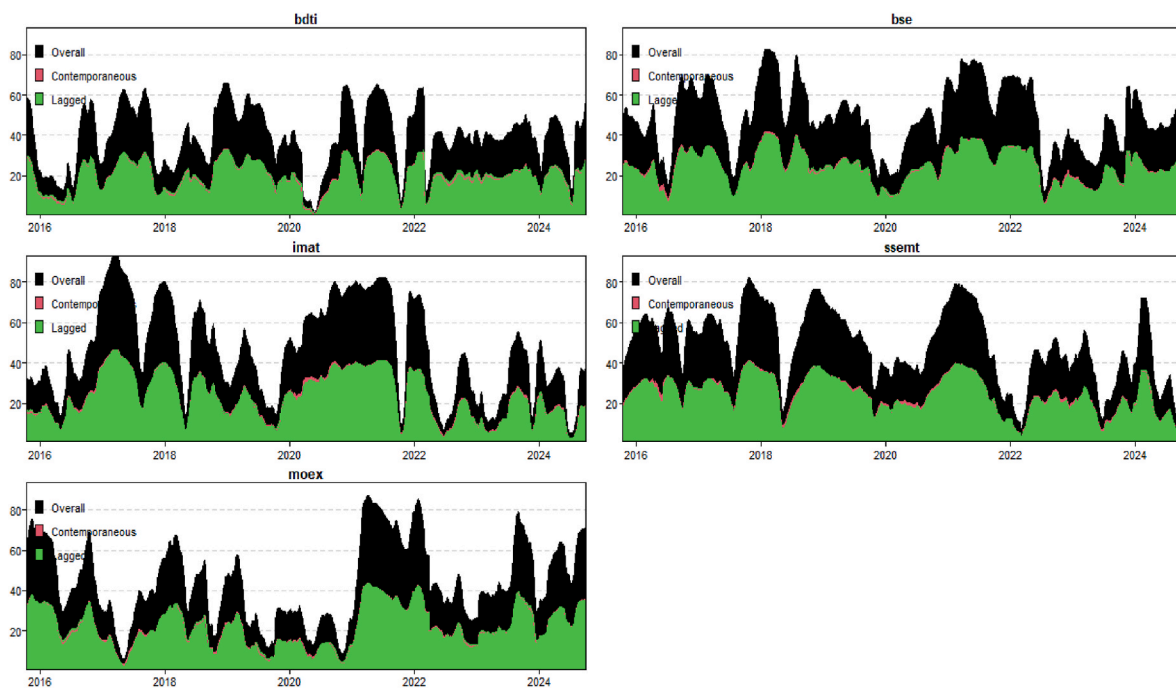


Fig. 4. To total directional connectedness.

chemical sector, leading to a close relationship with the BDTI. The sensitivity of this sector to changes in energy prices and transportation costs makes the directional effect from the BDTI more pronounced during crisis periods. These findings show that the BDTI affects the energy and chemical sector indexes of the BRIC countries in response to price fluctuation in global markets and clearly demonstrates that

fluctuation in energy markets spills over to other markets through maritime transportation costs.

Fig. 6 shows the net pairwise connectedness between the sectoral indexes of the BRIC countries and the BDTI. In the “net pairwise directional connectedness” analysis, the interactions of each index with the other indexes are portrayed as net positive or negative effects. This

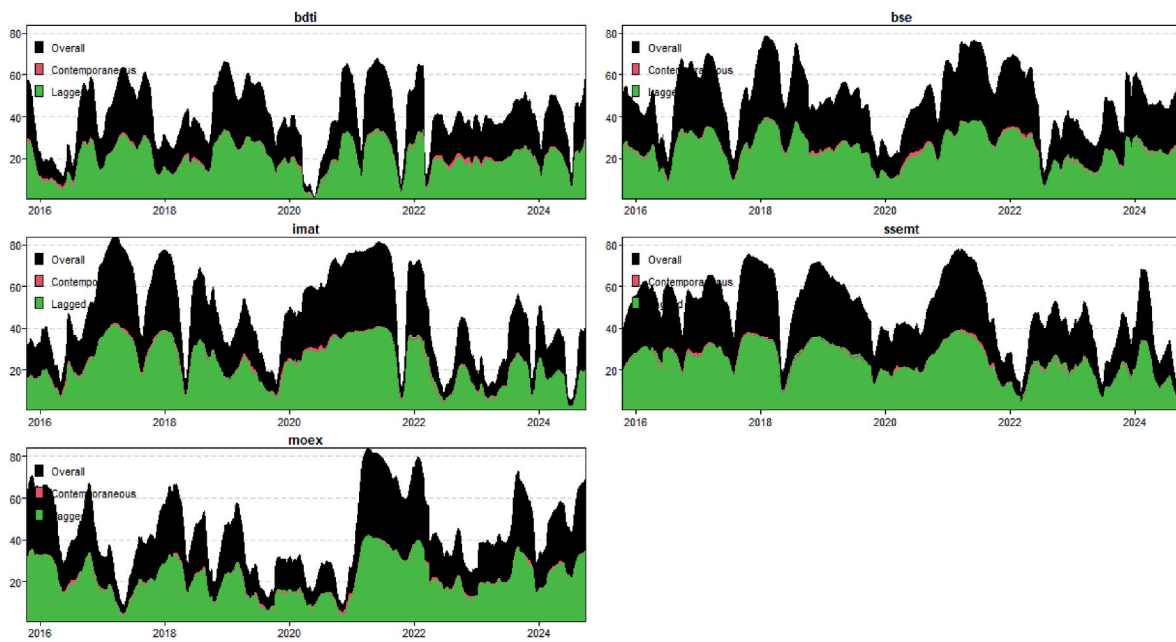


Fig. 5. From total directional connectedness.

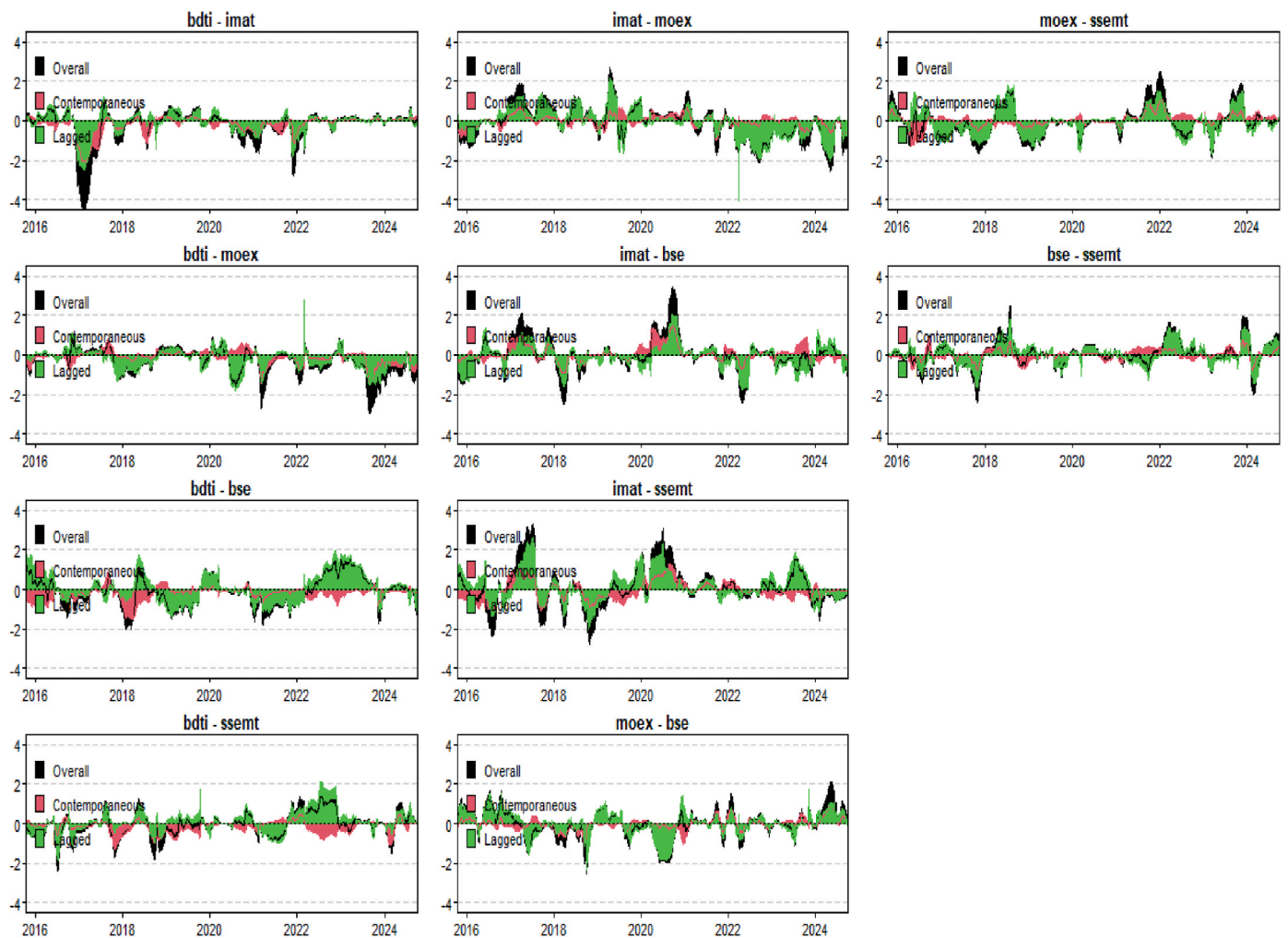


Fig. 6. Net pairwise directional connectedness.

provides information on which indexes influence others more and which indexes are recipients of more influence.

Fig. 6 clearly shows the existence of pairwise connectedness, especially in the interaction of the energy and chemical sector indexes with the BDTI. For example, Russia's MOEX Chemicals index has a pairwise relationship with the BDTI, which is generally influenced by the BDTI but has a reciprocal effect in certain periods. This relationship explains the impact of exogenous shocks and geopolitical risks that create volatility in Russia's energy sector on the chemical sector and its impact on maritime transportation costs. Similarly, India's dependence on energy imports drives the pairwise connectedness between India's S&P BSE Oil & Gas index and the BDTI. Although the changes in the BDTI have a high impact on this index, the cost pressure from India's energy sector directly affects the BDTI, especially when energy prices are rising.

The connectedness between China's SSEMT Materials Index and the BDTI clearly shows the direct impact on transportation costs of China's global demand for raw materials. This indicates the directional impact of increases in China's production capacity and import demand on the BDTI. At the same time, the pairwise relationship has an equilibrium at which the BDTI affects the SSEMT Materials index, especially when raw materials costs are rising.

In conclusion, Fig. 6 reveals the dynamic nature of interactions between the BRIC countries' sectoral indexes and the BDTI and explains the pairwise connectedness structure of energy price fluctuation on these indexes. These findings demonstrate the connectedness of maritime transportation and energy markets, showing that energy costs spill over to other sectors and are reflected in the maritime transportation index during crisis periods.

The overall level of connectedness in Fig. 7 reveals the spillover of energy price fluctuations to the sectoral indexes of the BRIC countries and the existence of a tight connectedness between the BDTI and these indexes. This strong connectedness between energy and transportation indexes makes the effects of Russia's MOEX Chemicals and India's S&P BSE Oil & Gas indexes on the BDTI particularly pronounced. The sensitivity of these sectors to changes in transportation costs means that shocks in energy prices are quickly reflected in the transportation index.

China's SSEMT Materials index also shows high connectedness with the BDTI as global demand for raw materials increases, revealing that the Chinese economy's import dependence and production capacity increase affect maritime transportation costs. In this context, when China's industrial production demand increases, its dependence on the BDTI becomes stronger.

Finally, Fig. 7 puts the connectedness measures in a dynamic perspective, showing changes in the connectedness of the energy and transportation sectors over time and in which periods it increased. These findings demonstrate the connectedness of global energy and trade markets with the indexes in the BRIC countries, and the strengthening of connectedness between these sectors, especially in times of crisis, showing the importance of policy makers' strategies for managing energy and transportation costs.

In this study, our analysis of dynamic interactions between sectoral indexes of the BRIC countries and the BDTI reveals significant connectedness between maritime transportation costs and the energy sector. The results show that Russia's MOEX Chemicals Index and India's S&P BSE Oil and Gas Index are highly correlated with the BDTI. China's SSEMT Materials index is also highly correlated with the BDTI in a similar direction, supporting the impact of China's global demand for raw materials on transportation costs. The results suggest that the sectoral characteristics of the BRIC countries play an important role in the transmission of energy price fluctuations to the maritime transportation index.

This study shows that dependence on maritime transportation costs (the BDTI) is higher for some sectors than others. These varying levels of dependence among sectors are believed to be associated with each sector's structural characteristics and economic dynamics. For instance, India's oil and gas sector is highly dependent on energy imports, and the structure of this sector is more sensitive to increases in maritime transportation costs. This sensitivity arises from the direct impact of fluctuations in global energy prices on sectoral costs. Similarly, Russia's chemical sector is vulnerable to energy price fluctuations, because of the structure of Russia's energy-intensive production and the direct impact of rising energy prices on the chemical sector. However, China's raw materials sector is highly correlated with the BDTI because of its export-oriented nature, which stems from the sector's substantial reliance on global demand.

6. Discussion

The results of the study detail the effect of energy price volatility on the pairwise dynamic connectedness between the BRIC countries' energy and chemical sector indexes and the BDTI. Fig. 4 shows the directional effects from the BRIC sectoral indexes to the BDTI, which show that countries with high energy demand, such as China (in its SSEMT Materials index) and India (via its S&P BSE Oil & Gas index), in

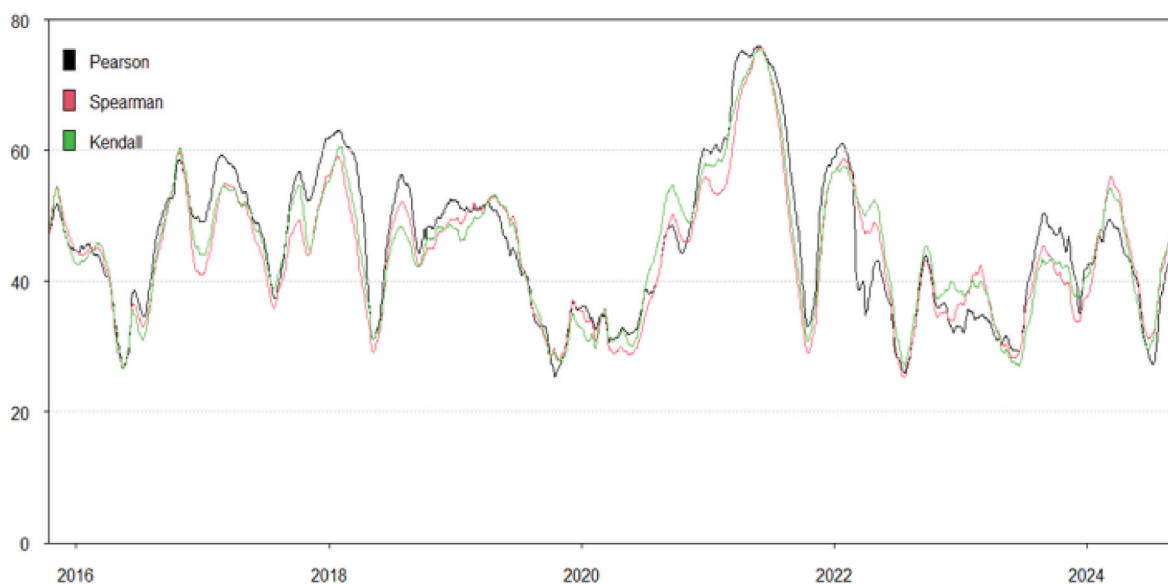


Fig. 7. Connectedness measures.

particular, contribute directly to transportation costs. For example, China's dependence on commodity imports and India's dependence on energy imports increase the cost pressure on ocean transportation costs and have an upward impact on the BDTI. These interactions highlight the sensitivity of the BRIC countries to fluctuations in global energy prices and the close link between their energy needs and rising maritime transportation costs.

Fig. 5 shows the impact of the BDTI on the indexes of BRIC countries, indicating that changes in transportation costs increase the volatility of these indexes. According to the results, fluctuations in the BDTI cause sudden changes in the sectors of countries with high energy consumption, such as India, Russia, and China. In particular, Russia's MOEX Chemicals index is strongly affected by the BDTI because of the relationship between Russia's energy production and its chemical sector. Sea transportation costs in Russia's chemical sector are destabilized by energy price fluctuations, which increases volatility in the chemical sector. In countries that are highly dependent on energy imports, such as India and China, the impact of the BDTI on sectoral indexes further reinforces the link between transportation costs and energy costs. In particular, the strong impact of energy cost fluctuations on transportation costs in India's S&P BSE Oil & Gas index is consistent with India's dependence on oil imports.

In this context, the findings on TO and FROM directional connectedness indicate the strength of the pairwise connectedness between the transportation and energy sectors of BRIC countries and that this interaction intensifies during periods of economic volatility. Increases in energy prices directly impact the sectoral indexes of the BRIC countries, making this connectedness with the BDTI more pronounced, especially during crisis periods. These findings reveal the connectedness of the energy and maritime transportation sectors, explaining the impact of energy price fluctuations on global trade costs and emphasizing the dynamic relationship between these indexes in terms of global market connectedness.

Our findings provide significant insights into the economic realities of the BRIC countries, shedding light on the financial resilience of publicly traded companies and their impact on sectoral performance. India's oil and gas sector is 87 percent dependent on energy imports, a reliance that intensifies the effects of energy price fluctuations on the sector. Companies in this sector are financially vulnerable because of the severe threats posed by rising import costs to operational expenses and profitability. For example, for an Indian oil company, higher energy prices coupled with higher transportation costs undermine price stability in the domestic market and weaken its international competitiveness.

Similarly, China's primary materials sector is export oriented because of its role in global production chains, and a significant portion of its revenue derives from international demand. This reliance amplifies the impact of rising transportation costs, driven by increased production, on the financial performance of firms in the sector. For instance, a Chinese steel company with a high volume of production may face limited options for pricing strategies due to transportation cost fluctuations that directly affect operational expenses.

Although Russia has substantial energy production capacity, its chemical sector is vulnerable to high energy costs. During periods of heightened geopolitical risk, rising energy prices significantly increase the operational costs of companies in this sector, and transportation costs exacerbate this burden. This is identified as a critical factor that negatively affects the competitiveness of these companies in global markets.

These findings reveal that sectoral dependence and vulnerability are influenced not only by energy costs but also by the economic structures of countries and the decision-making processes at the corporate level. The study offers a striking perspective on the heterogeneity of sectoral dependence on maritime transportation costs, grounded in the economic realities of countries and the operational frameworks of companies.

7. Conclusion

This study examines the dynamic linkages between the BDTI and the chemical, oil/gas, and raw materials sectoral indexes of the BRIC countries using the generalized R^2 method. The findings reveal the existence of both simultaneous and lagged spillover effects between energy transportation costs and the sectoral indexes of the BRIC countries. Our analysis shows that the impact of energy price fluctuations and changes in transportation costs on the sectoral indexes of the BRIC countries increase, especially during crisis periods. In this context, these findings help illuminate the impact of energy price fluctuations on economic growth and sectoral performance. Our study suggests that sectors that are sensitive to energy costs should adopt new approaches to manage volatility in financial markets.

7.1. Implications

This study analyzes the pairwise relationships between the BDTI and the indexes of the chemical, oil/gas, and raw materials sectors of the BRIC countries. The findings reveal that the interactions of BRIC countries' sectoral indexes with the BDTI intensify in certain periods. In particular, Russia's MOEX Chemicals Index and India's S&P BSE Oil and Gas Index interact strongly with the BDTI and are strongly affected by changes in transportation costs. These relationships become even more pronounced during periods of crisis and geopolitical risk.

In particular, the Ukraine crisis and the economic sanctions imposed on Russia in 2022 caused significant fluctuations in Russia's energy and chemical sectors. During this period, the interaction between the MOEX Chemicals Index and the BDTI intensified, revealing the impact of geopolitical uncertainty on sectoral indexes. Similarly, the US-China trade war in 2018 increased cost pressures on China's raw materials demand and India's oil imports, which strengthened the interaction between the BDTI and the sectoral indexes of these countries. These periods of crisis demonstrate that maritime transportation costs can quickly spill over to other sectors.

7.2. Recommendations

In light of these findings, more proactive policies should be developed by BRIC countries against sudden or unexpected increases in freight rates arising from geopolitical risk. For example, a "freight risk management mechanism" among the BRIC countries could help build a maritime transportation system that is more resilient to such external shocks. This mechanism could contribute to more coordinated logistics strategies, the development of common marine insurance programs, and the reduction of sectoral cost pressures. Moreover, taking into account the impact of the BDTI on sectoral indicators, BRIC countries should update their economic planning and market supervision mechanisms based on the signals from this index. By using the BDTI as a forecasting tool in their economic and financial systems, these countries would be able to monitor the sectoral impacts of changes in transportation costs more closely.

Accordingly, the BRIC countries need to develop stronger cooperation in energy and logistics. Optimizing energy and raw materials transportation routes would offer cost advantages, especially considering China's raw materials demand pressure during the US-China trade war in 2018. Through developing common logistics strategies, the BRIC countries could reduce their transportation costs and make their supply chains more resilient. By structuring their economic and financial systems in a more integrated manner, these countries can enhance the sustainability of global trade.

They should also employ financial instruments more effectively to manage maritime transportation costs. The use of derivatives, forward contracts, and energy transportation insurance, for example, would enable shipowners to manage their cost risks, protecting them against sudden cost spikes, as were experienced during crises in 2014 and 2018.

Moreover, the use of artificial intelligence–based data analytics systems and machine learning techniques can contribute to the prediction of fluctuations in maritime transportation costs and design of proactive strategies. In this way, actors in the transportation sector would be better prepared for uncertainty in times of crisis.

This paper focuses on the BRIC countries, but evaluation of this relationship would benefit from a broader perspective. Future studies would do well to include sectoral indexes of other developed and developing countries in order to examine the effects of energy price fluctuations more comprehensively at a global scale. Moreover, an understanding of the effects of uncertainty in energy markets on a sectoral basis would be enhanced by considering different types of energy (oil, natural gas, renewable energy, etc.) and comparing the sectors' responses to these energy types. Finally, analyzing these relationships with econometric models, such as structural breaks and regime shifts, might offer new approaches for understanding the long-term effects of energy crises on sectoral performance.

Author contribution statement

This study was jointly prepared by Şerife Akıncı Tok and Savaş Tarkun, who contributed equally to all aspects of the research. Both authors were involved in the conceptualization, methodology development, data analysis, interpretation of the results, and manuscript preparation.

References

- Anscombe, F. J., & Glynn, W. J. (1983). Distribution of the kurtosis statistic b_2 for normal samples. *Biometrika*, 70(1), 227–234. <https://doi.org/10.1093/biomet/70.1.227>
- Asif, M., & Muneer, T. (2007). Energy supply, its demand and security issues for developed and emerging economies. *Renewable and Sustainable Energy Reviews*, 11(7), 1388–1413. <https://doi.org/10.1016/j.rser.2005.12.004>
- Aslam, F., Hunjra, A. I., Bouri, E., Mughal, K. S., & Khan, M. (2023). Dependence structure across equity sectors: Evidence from vine copulas. *Borsa Istanbul Review*, 23(1), 184–202. <https://doi.org/10.1016/j.bir.2022.10.003>
- Balli, F., Balli, H. O., Dang, T. H. N., & Gabauer, D. (2023). Contemporaneous and lagged R2 decomposed connectedness approach: New evidence from the energy futures market. *Finance Research Letters*, 57(July). <https://doi.org/10.1016/j.frl.2023.104168>
- Balli, H. O., Balli, F., & Louis, R. J. (2013). Time-varying spillover effects on sectoral equity returns. *International Review of Finance*, 13(1), 67–91. <https://doi.org/10.1111/j.1468-2443.2011.01143.x>
- Baur, D. G., & Hoang, L. T. (2021). The importance of spillovers. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3973795>
- Benlagha, N., Karim, S., Naeem, M. A., Lucey, B. M., & Vigne, S. A. (2022). Risk connectedness between energy and stock markets: Evidence from oil importing and exporting countries. *Energy Economics*, 115(September), Article 106348. <https://doi.org/10.1016/j.eneco.2022.106348>
- Billah, M., Karim, S., Naeem, M. A., & Vigne, S. A. (2022). Return and volatility spillovers between energy and BRIC markets: Evidence from quantile connectedness. *Research in International Business and Finance*, 62(November 2021), Article 101680. <https://doi.org/10.1016/j.ribaf.2022.101680>
- Choi, K. H., & Yoon, S. M. (2020). Asymmetric dependence between oil prices and maritime freight rates: A time-varying copula approach. *Sustainability*, 12(24), 1–16. <https://doi.org/10.3390/su122410687>
- Cui, J., Goh, M., Li, B., & Zou, H. (2021). Dynamic dependence and risk connectedness among oil and stock markets: New evidence from time-frequency domain perspectives. *Energy*, 216(C).
- D'Agostino, R. B. (1970). Transformation to normality of the null distribution of g . *Biometrika*, 57(3), 679–681. <https://doi.org/10.1093/biomet/57.3.679>
- Dai, L., Hu, H., Tao, Y., & Lee, S. (2020). The volatility transmission between crude oil market and tanker freight market. *International Journal of Shipping and Transport Logistics*, 12(6), 619. <https://doi.org/10.1504/IJSTL.2020.111122>
- Dang, T. H. N., Balli, F., Balli, H. O., Gabauer, D., & Nguyen, T. T. H. (2024). Sectoral uncertainty spillovers in emerging markets: A quantile time–frequency connectedness approach. *International Review of Economics & Finance*, 93(PB), 121–139. <https://doi.org/10.1016/j.iref.2024.04.017>
- Dang, T. H. N., Nguyen, C. P., Lee, G. S., Nguyen, B. Q., & Le, T. T. (2023). Measuring the energy-related uncertainty index. *Energy Economics*, 124(December 2022), Article 106817. <https://doi.org/10.1016/j.eneco.2023.106817>
- Diebold, F. X., & Yilmaz, K. (2012). Better to give than to receive: Predictive directional measurement of volatility spillovers. *International Journal of Forecasting*, 28(1), 57–66. <https://doi.org/10.1016/j.ijforecast.2011.02.006>
- Diebold, F. X., & Yilmaz, K. (2014). On the network topology of variance decompositions: Measuring the connectedness of financial firms. *Journal of Econometrics*, 182(1), 119–134. <https://doi.org/10.1016/j.jeconom.2014.04.012>
- Elliott, B. Y. G., Rothenberg, T. J., & Stock, J. H. (1996). Efficient tests for an autoregressive unit root. *Econometrica*, 64(4), 813–836.
- Fisher, T. J., & Gallagher, C. M. (2012). New weighted portmanteau statistics for time series goodness of fit testing. *Journal of the American Statistical Association*, 107(498), 777–787. <https://doi.org/10.1080/01621459.2012.688465>
- Guo, Y., Li, P., & Li, A. (2021). Tail risk contagion between international financial markets during COVID-19 pandemic. *International Review of Financial Analysis*, 73, Article 101649. <https://doi.org/10.1016/j.irfa.2020.101649>
- Hedström, A., Zelander, N., Junttila, J., & Uddin, G. S. (2019). Emerging market contagion under geopolitical uncertainty. *Emerging Markets Finance and Trade*, 1–25. <https://doi.org/10.1080/1540496x.2018.1562895>
- Jarque, C. M., & Bera, A. K. (1980). Efficient tests for normality, homoscedasticity and serial independence of regression residuals. *Economics Letters*, 6(3), 255–259. [https://doi.org/10.1016/0165-1765\(80\)90024-5](https://doi.org/10.1016/0165-1765(80)90024-5)
- Jones, C. M., & Kaul, G. (1996). Oil and the stock markets. *The Journal of Finance*, 51(2), 463–491. <https://doi.org/10.1111/j.1540-6261.1996.tb02691.x>
- Kapar, B., Billah, S. M., Rana, F., & Balli, F. (2024). An investigation of the frequency dynamics of spillovers and connectedness among GCC sectoral indices. *International Review of Economics & Finance*, 89, 1442–1467. <https://doi.org/10.1016/j.iref.2023.09.004>. June 2022.
- Khan, K., Su, C. W., Tao, R., & Umar, M. (2021). How often do oil prices and tanker freight rates depend on global uncertainty? *Regional Studies in Marine Science*, 48, Article 102043. <https://doi.org/10.1016/j.rsma.2021.102043>
- Mobarek, A., Muradoglu, Y. G., Mollah, S., & Hou, A. J. (2016). Determinants of time varying Co-movements among international stock markets during crisis and non-crisis periods. *Journal of Financial Stability*.
- Qi, X., Zhang, W., Sun, L., Hu, Z., & Ning, Z. (2023). Navigating the tides of uncertainty: Exploring the complex relationship between global economic policy and crude oil transportation. *Maritime Economics & Logistics*, 6. <https://doi.org/10.1057/s41278-023-00274-w>
- Sadorsky, P. (1999). Oil price shocks and stock market activity. *Energy Economics*, 21(5), 449–469. [https://doi.org/10.1016/S0140-9883\(99\)00020-1](https://doi.org/10.1016/S0140-9883(99)00020-1)
- Shahbaz, M., Khan, S., & Tahir, M. I. (2013). The dynamic links between energy consumption, economic growth, financial development and trade in China: Fresh evidence from multivariate framework analysis. *Energy Economics*, 40, 8–21. <https://doi.org/10.1016/j.eneco.2013.06.006>
- Shahzad, S. J. H., & Naifar, N. (2022). Dependence dynamics of Islamic and conventional equity sectors: What do we learn from the decoupling hypothesis and COVID-19 pandemic? *The North American Journal of Economics and Finance*, 59(September 2021), Article 101635. <https://doi.org/10.1016/j.najef.2021.101635>
- Wang, Y., Cheng, S., & Cao, Y. (2022). How does economic policy uncertainty respond to the global oil price fluctuations? Evidence from BRICS countries. *Resources Policy*, 79(68), Article 103025. <https://doi.org/10.1016/j.resourpol.2022.103025>
- Yousaf, I., Beljid, M., Chaibi, A., & Ajlouni, A. A. L. (2022). Do volatility spillover and hedging among GCC stock markets and global factors vary from normal to turbulent periods? Evidence from the global financial crisis and covid-19 pandemic crisis. *Pacific-Basin Finance Journal*, 73.
- Zakeri, B., Paulavets, K., Barreto-Gomez, L., Echeverri, L. G., Pachauri, S., Boza-Kiss, B., Zimm, C., Rogelj, J., Creutzig, F., Ürge-Vorsatz, D., Victor, D. G., Bazilian, M. D., Fritz, S., Gielen, D., McCollum, D. L., Srivastava, L., Hunt, J. D., & Pouya, S. (2022). Pandemic, war, and global energy transitions. *Energies*, 15(17), 1–23. <https://doi.org/10.3390/en15176114>
- Zhang, X., & Guo, Q. (2024). How useful are energy-related uncertainty for oil price volatility forecasting? *Finance Research Letters*, 60(October 2023), Article 104953. <https://doi.org/10.1016/j.frl.2023.104953>
- Zhang, X., Yang, X., Li, J., & Hao, J. (2023). Contemporaneous and noncontemporaneous idiosyncratic risk spillovers in commodity futures markets: A novel network topology approach. *Journal of Futures Markets*, 43(6), 705–733. <https://doi.org/10.1002/fut.22407>