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Analyzing Fossil Fuel Commodities' Return Spillovers during the Russia and Ukraine Crisis in the Energy Market

Abstract

During the Russia and Ukraine crises, the energy market, including fossil fuel commodities, experienced significant global shocks. This research paper investigates the phenomenon of return spillover across the energy market amid the Russia and Ukraine conflict, utilizing the Diebold and Yilmaz Spillover Framework and EGRACH Model. The study examines daily frequency data from 24 February 2022 to 30 June 2023, focusing on the interconnectedness between various energy commodities: Brent Oil, Carbon Emissions, Crude Oil WTI, Gasoline, Heating Oil, and Natural Gas. The result of the study reports a total spillover index of 36%, indicating a significant spillover during the Russia and Ukraine conflict. Furthermore, the highest dynamic gross directional return spillovers have been reported in Brent Oil compared to the others. However, carbon emissions and natural gas have the lowest spillovers. The study significantly contributes to a deeper understanding of energy commodities by confirming the volatility persistence across the energy market based on the E-GARCH model.

Keywords: Energy Market, Return Spillover, Fossil Fuel commodities, Russia and Ukraine Crisis, Spillover Effect

1.0 Introduction

The energy market holds immense significance within the global economy (Alkathery, Chaudhuri, & Nasir, 2023; Irfan, Rehman, Razzaq, & Hao, 2023; Nasim, Ullah, Kim, & Hameed, 2023; Uddin et al., 2023; Zeqiraj, Sohag, & Soytaş, 2020), and any disruptions in this sector can have profound consequences for countries across the world. The COVID-19 pandemic has significantly affected the performance of the financial market across the world (Hasan, Mahi, Sarker, & Amin, 2021; H. Liu, Manzoor, Wang, Zhang, & Manzoor, 2020; Rakshit & Neog, 2022). The evidence also shows that the global economy has faced a potential level of substantial strain and instability (Bagchi et al., 2020; Jackson et al., 2020; Lee & Hussain, 2023; Ozili & Arun, 2023). Notably, the Russia and Ukraine crisis has played a pivotal role in the intensifying market volatility (Beraich, Amzile, Laamire, Zirari, & Fadali, 2022; Wu, Zhan, Zhou, & Wang, 2023). Recently, the Russia and Ukraine Crisis became one of the major events in the global economy, escalating tensions across the world in immediate political and social ramifications, but they also reverberated throughout various economic sectors, particularly the energy market (Balsalobre-Lorente, Sinha, & Murshed, 2023; Wicaksana & Ramadhan, 2022; Xin & Zhang, 2023).

The Russia-Ukraine conflict has emerged as a momentous and unparalleled event in Europe, drawing parallels to the monumental significance of World War II, which has created numerous challenges for the global economy (Bo, 2023; Yumeng Jiang, Sun, Hu, & Lu, 2023; Ma, 2023; Rose, Chen, & Wei, 2023). The Russia and Ukraine conflict has significantly affected the recovery process of the global economy from the COVID-19 pandemic (Arriola et al., 2023; Ljubotina & Raspor, 2022). As a matter of fact, Russia has a significantly prominent role in the global market as it stands among the leading exporters of oil and natural gas. Russia has been known for supplying energy to numerous countries worldwide. The energy exports from Russia substantially impact global energy prices and the market's overall stability (Nadig, 2023). The energy market experienced significant shocks during the Russia and Ukraine crisis in February 2022. The recent crisis has triggered potential shocks which can be attributed to factors such as geopolitical instability, supply of energy and market dynamics changes. The crisis between Russia and Ukraine has resulted in significant disruptions to the natural gas supply, primarily affecting European countries that depend on Russian gas transported through Ukrainian pipelines. Disputes concerning gas prices and transit fees between Russia and Ukraine have caused temporary interruptions and decreased gas flows, leading to energy shortages and price volatility. Resultantly, geopolitical uncertainties stemming from the conflict have triggered substantial disruptions and volatility in key energy commodities such as Brent Oil, Crude Oil WTI, Gasoline, Heating Oil, and Natural Gas (J. Chen, Xiao, Bai, & Guo, 2023; Jaffe & O'Sullivan, 2012; Stern et al., 2014; Zhou, Huang, Gao, & Luo, 2024). This significant relationship has been evidenced

by the heightened unpredictability introduced by the conflict, impacting energy supply chains, production processes, and distribution networks. The intricate interplay of these factors magnifies the sway of geopolitical events on energy markets, creating a situation where changes in political dynamics are directly mirrored in market movements. Market participants and investors find themselves closely monitoring the evolving situation in the Russia-Ukraine conflict, recognizing its potential to disturb the stability and pricing of energy commodities (Chowdhury & Humaira, 2023a, 2023b; Kantomaa, 2022; Kuznetsov, Kvashnin, Lukonin, & Chetverikova, 2015).

Moreover, the Russia and Ukraine conflict has resulted in heightened price volatility within the global oil markets (Kemp, 2023; Northam, 2023). The uncertainties stemming from this crisis, geopolitical risks and apprehensions regarding potential disruptions in energy supply, have caused significant price fluctuations (Galetto, 2022; Nadig, 2023). These fluctuations have posed challenges for market participants in effectively planning and managing their operations. The ongoing Russia-Ukraine conflict has emerged as a pivotal geopolitical event, casting a profound impact on global energy markets (Al-Hasnawi, 2022; Chishti, Khalid, & Sana, 2023; Obi, Waweru, & Nyangu, 2023; Stulberg, 2015). A noticeable surge in volatility and disruptions has been observed within the energy sector, encompassing vital commodities such as oil, natural gas, and others. These intricate fluctuations create a web of interconnected challenges that necessitate thorough analysis. The evidence shows that previous studies have explored spillover effects in different crises, such as GFC (Choudhry & Jayasekera, 2014; Mensi, Hammoudeh, Nguyen, & Kang, 2016; Sui & Sun, 2016) and COVID-19 pandemic (Abuzayed, Bouri, Al-Fayoumi, & Jalkh, 2021; Shahzad, Bouri, Kristoufek, & Saeed, 2021; Si, Li, Xu, & Fang, 2021), there is a lack of comprehensive analysis specifically focused on the interdependencies and transmission of returns in the energy market during the Russia and Ukraine crises. Such disruptions in the energy market due to this geopolitical conflict highlighted the need for a comprehensive analysis of the returns spillover effect in the energy market.

Return spillover refers to the transmission of financial shocks or disruptions from one market to another. Such spillovers can have wide-ranging consequences, including increased volatility, price fluctuations, and interconnected risks across various financial markets. Within the Russia and Ukraine Crisis context, examining return spillover in energy markets offers valuable insights into the transmission of shocks, the interdependence of energy markets, and the potential vulnerabilities and contagion effects they may encounter during geopolitical instability. There are several reasons for understanding the return spillover effects in the energy market during geopolitical crises such as Russia and Ukraine. Wang and Guo (2018) study examines the dynamic spillovers among the carbon and energy markets by adopting the Diebold and Yilmaz (2012) spillover framework. The findings of the study identified potential spillover effects in the market. The study highlighted that the WTI

oil market emerges as the most influential transmitter of spillover to the system. At the same time, the natural gas market also exhibits a prominent spillover effect on the carbon market. Moreover, the investigation highlights the presence of significant mean spillover from the oil and natural gas markets to the carbon market, particularly under extreme conditions. This revealed that the Russia and Ukraine crisis has a potential impact on the energy market, and it is important to identify such spillover patterns in the market. Moreover, Mu, Huang, Li, and Hou (2022) study adopted the VAR-based connectedness framework to examine the dynamic volatility spillover behavior among the international stock market during the Russia and Ukraine crises. The study's findings highlighted that the trend in the overall spillovers among the market aligns with the Russia and Ukraine crisis. The study also reveal that the Russian stock market serves a predominant source of risk, furthermore, it is highlighted that there is a potential for enduring volatility spillovers from the Russian stock market to other international markets.

In an era of evolving global economic dependencies on energy resources, unraveling the nuanced dynamics during geopolitical turmoil becomes crucial for stakeholders like policymakers, investors, and market participants. The motivation driving this study stems from the urgent necessity to comprehend the complex relationships between various energy commodities in the aftermath of the Russia-Ukraine conflict. A crucial investigation into the phenomenon of return spillover among these markets becomes essential to grasp the intricacies and outcomes of this crisis in energy markets. Therefore, this paper aims to bridge this gap by investigating the magnitude of directional returns spillover effects by using Diebold and Yilmaz (2012) spillover framework. The study sheds light on the interconnectedness of energy markets during geopolitical crises and evaluates the influence of key events and market characteristics on return spillover patterns.

Our study employs the Diebold and Yilmaz (2012) Spillover Framework to explore the spillover effects within the energy market, aiming to illuminate how the conflict resonates through different dimensions of the energy sectors. This study examines the gross directional return spillover among the potential energy commodities during the Russia and Ukraine crisis. Our study identified and quantified the magnitude of returns spillover transmission in the energy market regarding the Russia and Ukraine crisis, with a total return spillover value of 36.63%. The study's results also confirmed the high level of gross directional spillovers among energy commodities at the beginning of the Russia and Ukraine crisis.

This undertaking transcends academic pursuit and is a practical guide for understanding the immediate and long-term implications for global energy markets. Consequently, our study seeks to offer valuable insights that can guide strategic decision-making, facilitate effective risk management,

and inform policy responses in navigating the challenges arising from geopolitical unrest within the energy landscape. This study has novel contributions to the existing literature in various ways. Firstly, this study investigated the transmission of returns spillover in the energy market during the Russia and Ukraine crisis by adopting the ideal method known as Diebold Yilmaz Spillover Framework. Secondly, this study provides a rigorous and comprehensive analysis, yielding valuable insights into the interconnectedness and transmission of returns across various energy markets in the face of geopolitical crises known as the Russia and Ukraine Conflict. While prior studies have explored spillover effects in diverse crises and regions, there is a distinct lack of understanding regarding the energy market dynamics regarding the Russia and Ukraine crises. Consequently, this study bridges a significance in the literature by delivering an in-depth analysis of return spillovers in the energy market specifically during the Russia and Ukraine crises. Additionally, this study provides valuable insights into the degree of contagion and the potential risks associated with political tensions. Lastly, this study provides potential insights into to the policymakers and financial investors regarding the spillover shocks across energy markets.

This paper is structured as follows: the subsequent section presents the Literature Review, section 3 describes the data description and methodology, section 4 presents the empirical results, and section 5 concludes the study.

2. Literature Review

This section reviewed the existing literature and established our study's base. Numerous research works have delved into an examination of return spillovers in energy markets during periods of crisis (Elgammal, Ahmed, & Alshami, 2021; Naeem, Rehman, Ahmad, Vo, & Karim, 2023; Rehman, Nautiyal, Ghardallou, Vo, & Zeitun, 2023; Zeng, Lu, & Ahmed, 2023). Certain scholars have explored the spillover effects between oil-producing and oil-importing regions during conflicts and crises. These investigations have shed light on how geopolitical events can result in substantial return spillovers and increased volatility within energy markets. However, only a limited studies have specifically focused on the crisis period of Russia and Ukraine and its influence on the energy market, adopting the Diebold and Yilmaz (2012) Spillover Framework. Geopolitical tensions, particularly in regions abundant in energy resources, have been found to exert an influence on energy market dynamics (Cheikh & Zaied, 2023; Figueiredo, Soliman, Al-Alawi, & Sousa, 2022; Y. Liu, Han, & Xu, 2021). The existing literature indicates that events like political conflicts, trade disputes, and international sanctions can lead to directional return spillovers in energy markets. Understanding the patterns and factors driving these spillovers during the Russia and Ukraine crises can offer valuable insights for policymakers, investors, and market participants.

Recently, significant progress has been observed in the financial market research in terms of financial modeling. Several financial and economic research studies have been conducted after GFC to study the transmission of spillover effects in the financial market worldwide. Researchers have used various approaches to examine the transmission of spillovers globally in the financial market. Such as the GAS-DCS-Copula (Yuan & Yang, 2020), GARCH-BEKK model (X. Liu, An, Huang, & Wen, 2017), and GARCH-MIDAS model (C. Jiang, Li, Xu, & Liu, 2021). Due to technological development and globalization, the dynamics of financial market behavior have undergone significant transformations. Consequently, researchers are currently engaged in the development of frequency domain analytical approaches to gain profound insights into the underlying structure of the financial market. Diebold and Yilmaz (2012) spillover framework has gained widespread recognition as the most effective approach for assessing spillover effects in the financial market. Researchers have adopted this method over time in different financial markets, such as the stock market (Grobys, 2015; Hung & Vo, 2021; Mensi, Boubaker, Al-Yahyaee, & Kang, 2018) and exchange rate (Akanni, 2020; Mishra, Pradhan, Tiwari, Dash, & Aruna, 2020; Salisu & Ayinde, 2018). Furthermore, Kumar (2013) conducted a study in which he applied the method and econometric models proposed by Diebold and Yilmaz (2012) study returns spillover behaviors in IBSA economies in the context of exchange rates and stock prices. The study's findings revealed that a significant bidirectional volatility spillover exists between the foreign exchange and stock markets. Moreover, the research results confirmed the presence of both volatility and returns spillover across the financial markets. Notably, the study highlighted that the stock market played a more prominent role in transmitting spillover effects in the IBSA countries compared to the foreign exchange markets.

Similarly, Naeem et al. (2023); and Billah et al. (2022) study investigate the dynamic spillover effect in the regional energy market (Asia, Europe, North America, Pacific region, and South America) and BRIC, respectively. The findings of the Naeem et al. (2023) study identified diverse return spillover effects across the regional energy market. The result also highlighted the asymmetric short and long-term return spillover effect in the regional energy market. The findings of the Billah et al. (2022) study highlighted that the return and volatility spillover among the market has been highly affected by the uncertain economic events over the time. The study also stated that Global Financial Crisis and COVID-19 pandemic play a significant role in the transmission of intensifying spillover effect between the energy and BRIC markets.

Ji, Bouri, Roubaud, and Shahzad (2018) highlighted the existence of substantial risk spillovers from energy to agricultural commodities. Ji, Zhang, and Geng (2018) findings indicate that Brent oil prices significantly influence changes in carbon prices and associated risks. Additionally, feedback effects are observed from the carbon market to other energy markets, with electricity prices being the

primary information receiver in the system. Notably, the level of connectedness within the volatility system is considerably higher compared to that in the returns system.

Our study holds significant importance within previous literature, addressing a critical gap in understanding the interconnectedness of energy commodities during geopolitical conflicts, particularly the Russia-Ukraine crisis. Prior research has explored the impact of geopolitical events on financial markets and energy prices. However, a comprehensive analysis of spillover effects within the energy market, especially considering multiple commodities, remains limited. The existing literature highlights the need for empirical studies that employ rigorous methodologies to quantify and analyze the dynamics of spillovers during periods of geopolitical uncertainty. This study contributes to the existing body of knowledge by focusing on the immediate impacts of the Russia-Ukraine conflict on various energy commodities, using the Diebold and Yilmaz (2012) Spillover Framework. This methodology was chosen based on its proven effectiveness in quantifying directional spillovers, providing a structured and transparent approach. By employing this methodology, we aim to build on and extend the insights from previous literature, offering a detailed examination of the interconnectedness of energy commodities during a significant geopolitical event, thereby contributing valuable knowledge to the field and guiding future research endeavors. The findings reveal a substantial total spillover index of 36%, indicating pronounced interconnectedness during the geopolitical turmoil. Brent Oil emerged as the primary recipient of dynamic gross directional return spillovers, underscoring its heightened sensitivity to external shocks. Additionally, the E-GARCH model shed light on the volatility behavior of these commodities, providing valuable insights into the dynamics of the energy market during periods of heightened geopolitical tension.

3.0 Methodology

3.1 Data

We are investigating the spillover of returns during the Russia-Ukraine conflict among energy markets. Prior to the crisis escalation, there was a period characterized by efforts towards integration and cooperation in the energy markets. The Russia-Ukraine conflict, which began on 24th February 2022, has instigated global tensions, particularly in the energy market. The conflict has triggered apprehensions regarding geopolitical stability and potential disruptions in energy supply. It has shed light on the susceptibilities present in energy infrastructure and has generated uncertainties about the possibility of further escalations. As a result, stakeholders diligently observe the repercussions on energy markets, encompassing aspects such as supply, transit routes, infrastructure integrity, and overall market stability. However, despite this integration's potential advantages, significant

challenges are associated with the interconnection among energy markets. Thus, examining the direction of return spillover during the Russia-Ukraine conflict is crucial, as it can provide valuable insights into which energy markets have a greater influence on others. We collected historical energy market data of Brent Oil, Carbon Emission, Crude Oil WTI, Gasoline, Heating Oil, and Natural Gas to examine the dynamic spillover returns. The data has been collected from investing.com on daily frequency ranging from 24th February 2023 to 30th June 2023. The financial return of energy commodities has been represented in the following equation.

$$R_t = \ln\left(\frac{P_t}{P_{t-1}}\right) \dots\dots\dots Eq. (1)$$

Where the current period returns are denoted by R_t , \ln indicates the natural logarithm function. Furthermore, P_t and P_{t-1} represents the prices at time period t , and $t - 1$.

Figure 1 shows the price trends of the energy commodities during the Russia and Ukraine crisis. As shown in Figure 1, the price of energy commodities dropped during the Russia and Ukraine crises. There a significant shift has been reported in the price of Brent Oil. Brent Oil has price dropped to 74 from 127.98 during the Russia and Ukraine Crisis. A similar pattern has been reported in the price behavior of Crude Oil and Heating Oil. Moreover, the Natural Gas price also experienced a significant decline at the end of December 2022. However, the price of Gasoline commodities have been increased in May and June 2022 and dropped during July 2022. On the other hand, Figure 2 shows the return fluctuation of all energy commodities during the ongoing crisis period. A potential level of return fluctuation can be observed in the return behavior of all six energy commodities. As shown in Figure 2, there are high fluctuations in the return of Brent Oil, Crude Oil, and Natural Gas commodities. Natural gas experienced a constant fluctuation in financial returns throughout the crisis, ranging from 0.13 to -0.18 (see Table 1). Similar behavior can be observed in the financial return of Brent Oil, ranging from 0.08 to -0.14 (see Table 1).

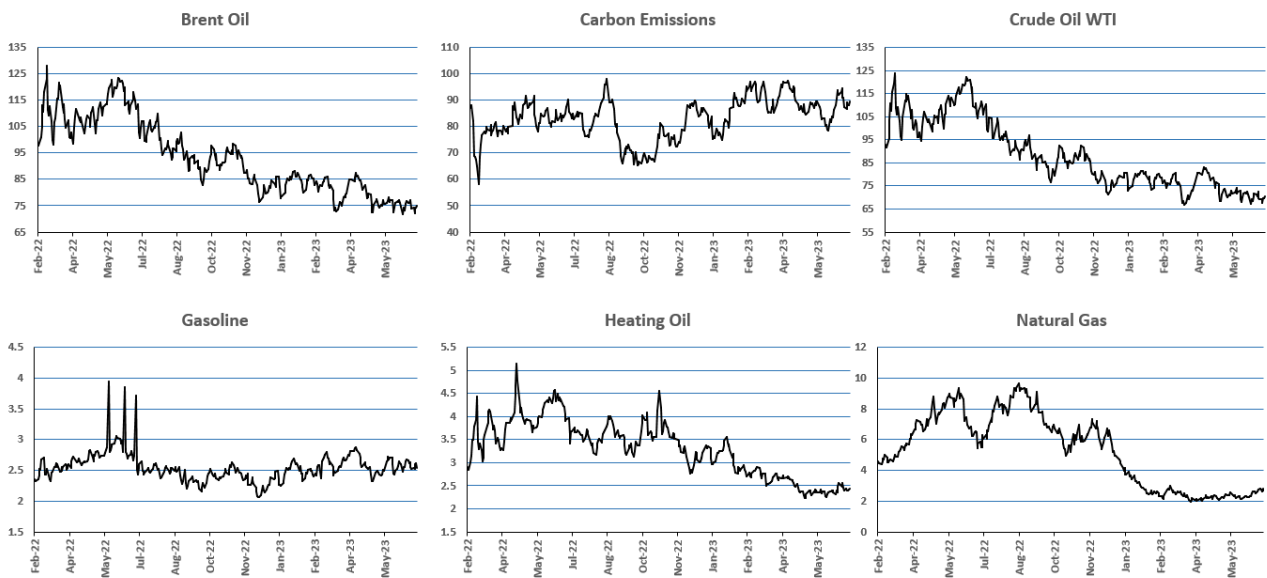


Figure 1: Price Trend of Energy Commodities

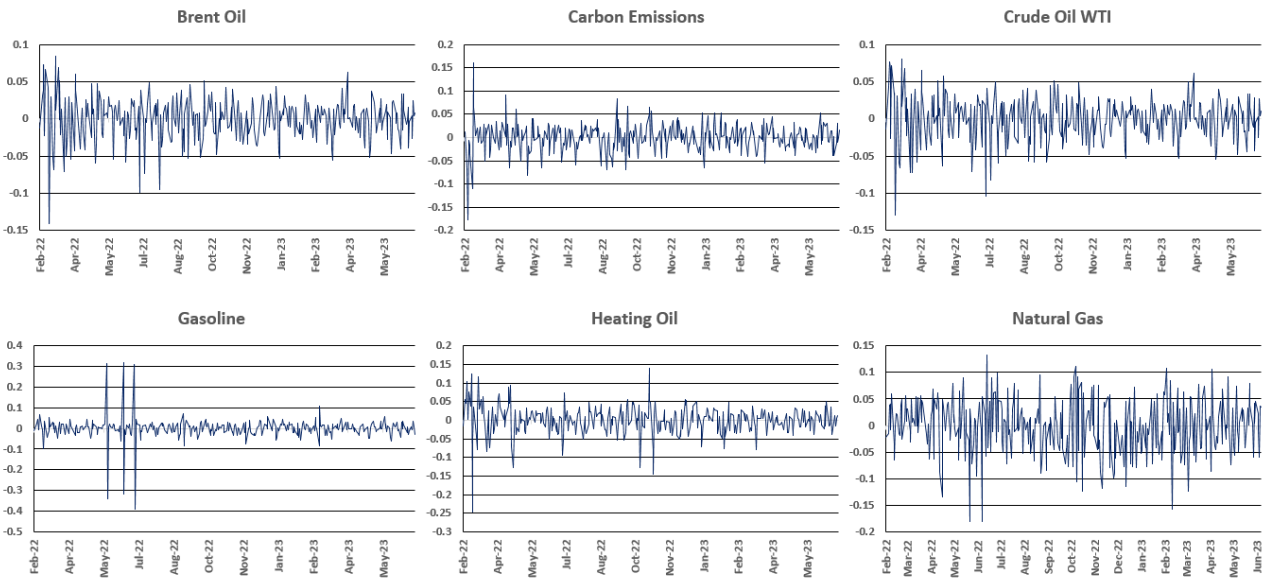


Figure 2: Return Fluctuations of Energy Commodities

3.2 Diebold and Yilmaz Spillovers Framework

We study the financial return spillovers within the energy market, adopting the spillover framework proposed by Diebold and Yilmaz (2012). This approach relies on variance decomposition and is associated with the n-variable vector autoregressive model. The DY spillover framework primarily focuses on total spillover, offering a considerable advantage as it allows us to estimate directional spillover.

Consider a covariance stationary n-variable $VAR(p)$ which is represented by:

$$x_t = \sum_{i=1}^p \Phi_i x_{t-i} + \varepsilon_t \dots\dots\dots Eq. (2)$$

Where $\varepsilon \sim (0, \Sigma)$ is an independently and identically disturbances vector. The MA representation can be written as $x_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i}$, where the n x n indicates the coefficient matrices of A_i , that follow the recursion $A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + \dots + \Phi_p A_{i-p}$, with A_0 is an identity matrix and $A_i = 0$ for $i < 0$. The coefficients of the MA, variance decompositions, or impulse response functions can reveal the dynamics of the system. The entire procedure relies on variance decomposition, which assists in analyzing the forecast error variance of each variable into segments in the content of its strong association with system shocks. Thus, utilizing variance decomposition, we can estimate the H-step-ahead error variance in the protection of x_i because of shocks to $x_j, \forall j \neq i$ for each i .

The KPPS H-step-ahead is denoted by $\theta_{ij}^g(H)$, where $H = 1, 2, \dots$, so we have

$$\theta_{ij}^g(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)} \dots\dots\dots Eq. (3)$$

Whereas σ_{jj} denotes the standard deviation of the error term for the j th equation. Σ shows the variance matrix of the error term. Furthermore, The selection vector is denoted by the e_i , equal to one for the i th element and zero otherwise.

In each row, the sum of elements of variance decomposition is not equal to 1, so it can be written as $\sum_{j=1}^N \theta_{ij}^g(H)$. Therefore,

$$\theta_{ij}^{\sim g}(H) = \frac{\theta_{ij}^g(H)}{\sum_{j=1}^N \theta_{ij}^g(H)} \dots\dots\dots Eq. 41)$$

Which will be applied in the spillover index computation, $\sum_{j=1}^N \theta_{ij}^{\sim g}(H) = 1$ and $\sum_{i,j=1}^N \theta_{ij}^{\sim g}(H) = N$.

The contribution of volatility in the development of the total spillover index is derived by KPPS variance decomposition:

$$S^g(H) = \frac{\sum_{i,j=1}^N \theta_{ij}^{\sim g}(H)}{\sum_{i,j=1}^N \theta_{ij}^{\sim g}(H)} \cdot 100 = \frac{\sum_{i,j=1}^N \theta_{ij}^{\sim g}(H)}{N} \cdot 100 \dots\dots\dots Eq. 51)$$

The total spillover index has represented the overall spillover shocks. Furthermore, we computed the directional spillover properties to the market i for all other markets j as:

$$S_i^g(H) = \frac{\sum_{j=1}^N \theta_{ij}^g(H)}{\sum_{i,j=1}^N \theta_{ij}^g(H)} \cdot 100 = \frac{\sum_{j=1}^N \theta_{ij}^g(H)}{N} \cdot 100 \quad \dots\dots\dots Eq.(6)$$

Similarly, we also computed the directional spillover by the market i to all other j markets:

$$S_i^g(H) = \frac{\sum_{j=1}^N \theta_{ji}^g(H)}{\sum_{i,j=1}^N \theta_{ji}^g(H)} \cdot 100 = \frac{\sum_{j=1}^N \theta_{ji}^g(H)}{N} \cdot 100 \quad \dots\dots\dots Eq.(7)$$

The net spillover for the energy commodities has been estimated using the above equation, which provides the overall summary of information for each variable.

$$S_i^g = S_i^g(H) - S_i^g(H) \quad \dots\dots\dots Eq.(8)$$

Furthermore, the net pairwise spillover of the energy returns can be written as

$$S_{ij}^g(H) = \left(\frac{\theta_{ji}^g(H)}{\sum_{i,k=1}^N \theta_{ik}^g(H)} - \frac{\theta_{ij}^g(H)}{\sum_{j,k=1}^N \theta_{jk}^g(H)} \right) \cdot 100 = \left(\frac{\theta_{ji}^g(H) - \theta_{ij}^g(H)}{N} \right) \cdot 100 \quad \dots\dots\dots Eq.(9)$$

3.3 EGARCH Model

The Exponential Generalized Autoregressive Conditional Heteroskedasticity (EGARCH) model, introduced by Nelson (1991), was employed in this study to address asymmetry within the conventional GARCH framework. The E-GARCH model has been used by various researcher to capture volatility behavior (Abdolbaghi, Sbour, & Bagheri Rafi, 2019; S. T. Chen & Haga, 2021; Yi Jiang, 2020; Labuschagne, Venter, & von Boetticher, 2015; Tarza Sokpo, Iorember, & Usar, 2017). The adopted model for this research study can multiply in the conditional variance. The E-GARCH model has been represented by:

$$\log h_t = (\omega - 1) + \alpha|\eta_{t-1}| + \gamma\eta_{t-1} + \beta \log h_{t-1} \quad \dots\dots\dots Eq.(10)$$

Where $\log h_t = E(\varepsilon_t^2 | I_{t-1})$, α, β , and γ are parameters for the estimation of the model.

Notably, the EGARCH model imposes no restrictions on the parameters as it operates on the logarithm of variance. Moreover, the reaction of financial investors towards bad news is more reactive than good news. Therefore, This characteristic emphasizes the asymmetrical impact of news on returns volatility, contributing to a more nuanced understanding of market dynamics.

4.0 Empirical Results

Table 1 shows the summary statistics of financial returns of Brent Oil, Carbon Emissions, Crude Oil WTI, Gasoline, Heating Oil, and Natural Gas during the Russia and Ukraine Crisis. These statistics provide insights into the energy market performance during the crisis, enabling a better understanding of their behavior during the crisis period. As shown in Table 1, Brent Oil, Crude Oil WTI, and Heating Oil experienced negative mean returns, suggesting a decline in financial returns in the energy market during the Russia and Ukraine crises. This aligns with expectations, as geopolitical tensions and disruptions in the region typically have a negative impact on the oil industry, leading to reduced returns. Conversely, Carbon Emissions, Gasoline, and Natural Gas exhibited positive mean returns, indicating increased returns. This could be attributed to factors such as increased demand or shifts in market dynamics that favored these variables during the crisis.

Table 1:

Summary Statistics of Energy Commodities

Note: Table 1 provides a comprehensive overview of the summary statistics for key energy commodities during the specified observation period. The statistics encompass measures of central tendency, dispersion, kurtosis, Skewness, minimum and maximum values, the Jarque Bera test results, and associated p-values. The energy commodities include (Brent Oil; Carbon Emissions; Crude Oil WTI; Gasoline; Heating oil; and Natural Gas). The study period is 24th February 2022 to 30th June 2023.

	<i>Brent Oil</i>	<i>Carbon Emissions</i>	<i>Crude Oil WTI</i>	<i>Gasoline</i>	<i>Heating Oil</i>	<i>Natural Gas</i>
Mean	-0.0008	0.0001	-0.0008	0.0002	-0.0005	-0.0014
Median	0.0013	0.0009	0.0027	0.0034	0.0004	0.0009
Standard Deviation	0.0277	0.0302	0.0289	0.0511	0.0374	0.0509
Sample Variance	0.0008	0.0009	0.0008	0.0026	0.0014	0.0026
Kurtosis	2.2601	5.5777	1.2757	30.5010	6.9221	0.3447
Skewness	-0.5939	-0.3228	-0.4349	-0.9244	-0.8541	-0.3404
Minimum	-0.1411	-0.1773	-0.1293	-0.3927	-0.2475	-0.1807
Maximum	0.0843	0.1614	0.0802	0.3191	0.1399	0.1335
Jarque Bera Test	90.5950	438.9100	32.9830	13063.0000	709.3400	8.1236
P Value	0.00	0.00	0.00	0.00	0.00	0.017
Observation	346	346	346	346	346	346

Furthermore, the dispersion in the financial returns around the mean has been measured by standard deviation. The finding of the study highlighted that Brent Oil, Carbon Emissions, Crude Oil WTI, and Heating Oil exhibited higher standard deviations, indicating greater volatility during the Russia and Ukraine Crisis. This indicates that the returns for these energy commodities experienced larger fluctuations, reflecting the uncertainty and turbulence in the market during the crisis period. The kurtosis values depict the shape of the return distribution. Gasoline displayed the highest kurtosis, indicating a relatively peaked distribution during the Russia and Ukraine crises. Furthermore, the highest Kurtosis value has been reported in the financial returns of Gasoline commodity with a Skewness value of -0.92, which indicates the existence of negative skewed behavior and asymmetric distribution in the series of the financial returns. Moreover, the Brent Oil, Carbon Emissions, Crude Oil WTI, Heating Oil, and Natural Gas imply a left-skewed distribution, indicating a higher probability of negative returns. This aligns with the expectation that the Russia and Ukraine crisis predominantly had a negative impact on the returns of energy commodities

Table 2 shows the Pearson correlation of six energy commodities during the Russian & Ukraine Crisis. The correlation analysis shows there are a number of positive correlations in the energy commodities. In the total set of correlation pairs 36 (6 X 6), it can be observed that the 34 correlation pairs exhibit positive behavior, which accounts for 94.4%, while the remaining exhibit negative behavior. The Brent oil commodity correlates significantly positively with Crude Oil WTI (0.946) and Heating Oil (0.663). The conflict potentially led to increased demand for heating oil and concerns about supply disruptions, which might have contributed to this correlation. However, the correlation between Brent Oil and Natural Gas was weakly positive (0.122), indicating some degree of association. However, natural gas prices are influenced by factors such as weather patterns and domestic production levels, which might have contributed to the weaker correlation during the conflict.

The row labeled 'directional to others' indicates considerable variation in gross directional return spillovers to the other energy commodities in the market. The finding of the study indicates the Brent Oil commodity exhibits the highest level of directional returns spillover to the energy commodities during the Russia and Ukraine crisis period with a value of 73.32, followed by Crude Oil WTI energy commodity with directional return spillover value of 70.1. Furthermore, the lowest transmission of the directional spillover to other commodities in the energy market has been reported in Carbon Emission (3.63), followed by Natural Gas (4.22).

Moreover, the "From" column in Table 4 represents the directional returns spillover transmitting from the other six energy commodities in the market to each individual energy commodity in the market. This research study identified a potential level of directional return spillover from other energy commodities. It is reported that Brent Oil received the highest level of return spillover from the other 5 energy commodities in the market during the Russia and Ukraine conflict with a directional spillover strength of 62.71, followed by Crude Oil with a directional spillover strength of 61.49. Furthermore, the lowest directional return spillover recipient from other market commodities is Carbon Emissions. The Carbon Emissions reported the directional spillover from the other five commodities with the lowest value of 0.84, followed by Natural Gas (6.28). Additionally, the Heating Oil was a major recipient of directional spillover from other five energy commodities with a value of 50.13 during the Russia and Ukraine Conflict.

The "Net Directional Connectedness" row indicates the highest net directional returns spillovers have been reported in Brent Oil commodity with a value of 10.6% (73.32 - 62.71), followed by Crude Oil WTI 8.61% (70.1 - 61.9). However, the lowest net directional spillovers have been reported in the Gasoline commodity with a value of -10.03% (28.31 - 38.34), followed by the Heating Oil commodity -9.92% (40.21 - 50.13), which indicates these commodities are a potential recipient of directional return spillovers in the energy market during the time period of Russia and Ukraine Conflict.

Table 4:**Return Spillovers Energy Commodities**

Note: Table 4 provides a results for Return Spillovers Energy Commodities during the specified observation period. The energy commodities include (Brent Oil; Carbon Emissions; Crude Oil WTI; Gasoline; Heating oil; and Natural Gas). The study time period is 24th February 2022 to 30th June 2023.

	Brent Oil	Carbon Emissions	Crude Oil WTI	Gasoline	Heating Oil	Natural Gas	From
Brent Oil	37.29	0.55	33.9	10.7	16.31	1.25	62.71
Carbon Emissions	0.16	99.16	0.18	0.08	0.35	0.07	0.84
Crude Oil WTI	34.59	0.39	38.51	10.57	14.69	1.25	61.49
Gasoline	15.63	0.3	14.89	61.66	6.83	0.69	38.34
Heating Oil	21.49	2.31	19.19	6.18	49.86	0.96	50.13
Natural Gas	1.45	0.08	1.94	0.78	2.03	93.72	6.28
Directional TO Others	73.32	3.63	70.1	28.31	40.21	4.22	219.79
Directional Including Own	110.61	102.79	108.61	89.97	90.07	97.94	
Net Directional Connectedness	10.61	2.79	8.61	-10.03	-9.92	-2.06	36.63%

Moreover, the directional return spillover among the energy market is combined as total spillover index, calculated by dividing the total off-diagonal column/row sum (219.79) by the total row sum, including diagonals (599.99). This index value, expressed as a percentage in the last row and last column of Table 4, indicates that, on average, from February 2022 to June 2023, 36.63% (219.79/599.99)

Furthermore, to investigate the volatility behavior of the energy commodities during the Russia & Ukraine crisis. We have applied the E-GARCH model to energy commodities to examine asymmetric volatility behavior during the Russia & Ukraine crisis. The finding of the study has a significant level of volatility behavior during the crisis. As shown in Table 5, the ARCH coefficients (Alpha) unveil the persistent influence of past squared returns on present volatility, while the GARCH coefficients (Beta) elucidate the enduring impact of past conditional variances on current volatility. Moreover, (Gamma) indicates the asymmetric behavior in the financial returns. The finding of the study shows

high level of volatility persistence in times of crisis. Carbon Emission indicates a high level of volatility persistence behaviors with a value of (GARCH = 0.998) at the significance level of 1%, followed by the Bent Oil (0.979).

Table 5:

Energy Commodity Volatility during Russia & Ukraine Crisis based on E-GARCH

Note: Table 5 provides a results for volatility of Energy Commodities during the specified observation period by using EGARCH model. The energy commodities include (Brent Oil; Carbon Emissions; Crude Oil WTI; Gasoline; Heating oil; and Natural Gas). The study time period is 24th February 2022 to 30th June 2023. Note: *** refers to 1% significance level, ** refers to 5% significance level, and * refers to 10% significance level.

	Brent Oil	Carbon Emissions	Crude Oil WTI	Gasoline	Heating Oil	Natural Gas
μ	-0.00096	-0.00084***	-0.00099	0.00173	-0.00049	-0.00089
ω	-0.15411***	-0.01010***	-0.17308	-9.05934***	-0.59310	-0.42094***
α (ARCH)	-0.00445	-0.10201***	-0.00012	0.13382*	0.08618	-0.01367
β (GARCH)	0.97952***	0.99862***	0.97680***	-0.32423**	0.91416***	0.92930***
$\alpha + \beta$	0.97507	0.89660	0.97668	-0.19041	1.00034	0.91563
γ (Gamma)	0.12380***	-0.03399***	0.16723	0.41558***	0.30222***	0.08512***
Log Likelihood	774.63170	752.25740	756.42830	735.07030	699.05330	544.02830
AIC	-4.4372	-4.3078	-4.332	-4.2085	-4.0003	-3.1042

Furthermore, the result of E-GARCH confirms the existence of potential asymmetric behavior in the financial returns of the Russia & Ukraine Crisis. The overall energy commodities exhibit positive asymmetric behavior except carbon emission (-0.0339). The highest asymmetric behavior has been reported in Gasoline (0.415) at a significance level of 1%, followed by Heating Oil commodity (0.30) at a significance level of 1%. The finding of the Exponential GARCH model implies a sustained environment of uncertainty and market turbulence associated with the geopolitical crisis. Investors and market participants may interpret these positive coefficients as indicating that the challenges and fluctuations related to the crisis are expected to persist, influencing decision-making regarding risk management and investments. Additionally, the significant asymmetric behavior in the financial returns of energy commodities suggests a positive relationship between past volatility and current returns, intimating that despite the challenges posed by the crisis, periods of increased market

turbulence may present opportunities for higher returns. These insights contribute to a nuanced understanding of market behavior during the Russia and Ukraine crises, aiding in more informed decision-making in finance and investments. Moreover, research has confirmed the existence of potential volatility behavior during the COVID-19 pandemic by using the E-GARCH model (Anastasia, Victor, & Ezekiel, 2022; Khan, Kayani, Khan, Mughal, & Haseeb, 2023; Ogbonna & Ejem, 2020).

The overall results confirm that the directional spillover has been significantly high in Brent Oil, Crude Oil, and Heating Oil during the COVID-19 pandemic. Furthermore, the impact of return spillover should be investigated using rolling windows. This method assists in the degree and nature of return spillover dynamics from 24th February 2022 to 30 June 2023. The finding of total returns is represented in Figure 3. The overall analysis of spillovers in the energy market confirms the spillover effect during the Russia and Ukraine crisis. As shown in Figure 3, significant fluctuations have been reported in the behavior of energy market return spillovers. Moreover, the highest total spillover was reported during May 2022, with a strength of 83.33. The total return spillover in the energy market fluctuates from approximately 40 to 80. Additionally, the energy market experienced a potential drop in total spillover in June 2022. The first cycle of the Russia and Ukraine crisis period began in February 2022 and experienced the highest spillover in the market. In the last few months, the market has experienced spillover behavior ranging between 40% to 60%.

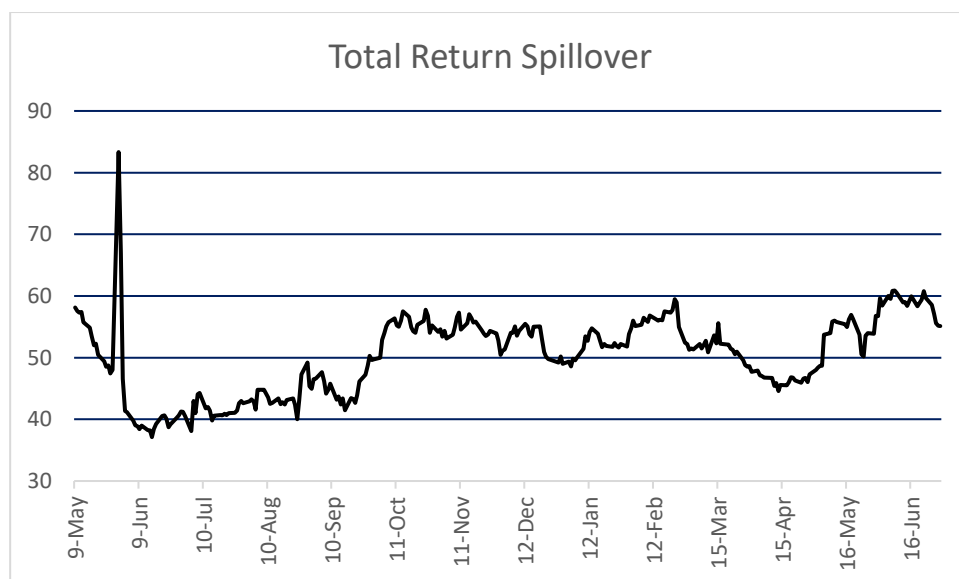


Figure 3: Total Return Spillovers in Energy market during Russia and Ukraine Crisis

Furthermore, Figure 4 indicates the directional return spillovers towards the energy commodities in the energy market, represented as “Directional to Others” in Table 4. During the Russia and Ukraine crisis, a significant level of spillover was reported in the market, as shown in Figure 4. Figure 4 shows that most of “To Spillover” fluctuation has been reported in Carbon Emissions, Heating Oil, and Natural Gas. Furthermore, it reported that Gasoline has showed the highest “To Spillover” at the beginning of the Russia and Ukraine crisis, approximately up to 70. Furthermore, Figure 5 shows the gross directional “From Spillovers” in the energy market during the Russia and Ukraine crises. The gross directional return spillover analysis shows that each energy commodity has experienced a potential level of returns spillover shock from other commodities in the market. As shown in Figure 5, there is significant increased has been reported in the Gasoline commodity. The return spillover from other commodities has increased over time during the Russia & Ukraine crisis, ranging from 4 to 12. Moreover, the Heating Oil also experienced significant return spillovers from the other commodities during the crisis.

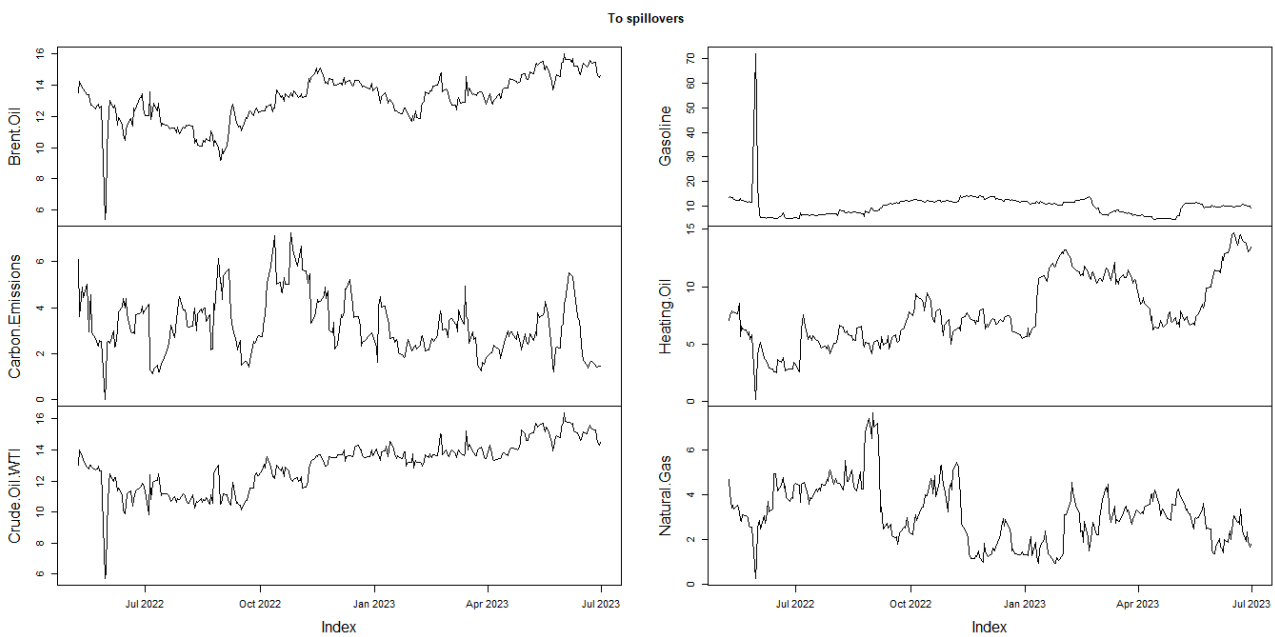


Figure 4: Gross Directional “To Spillovers” in Energy market during Russia and Ukraine Crisis

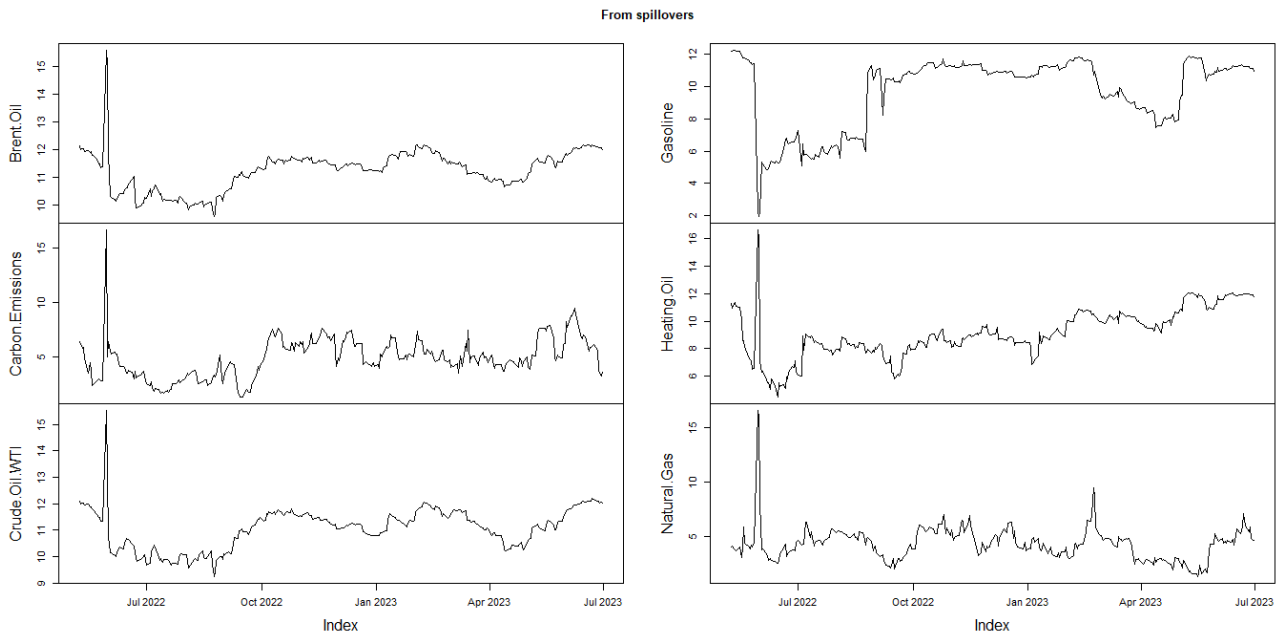


Figure 5: Gross Directional “From Spillovers” in Energy market during Russia and Ukraine Crisis

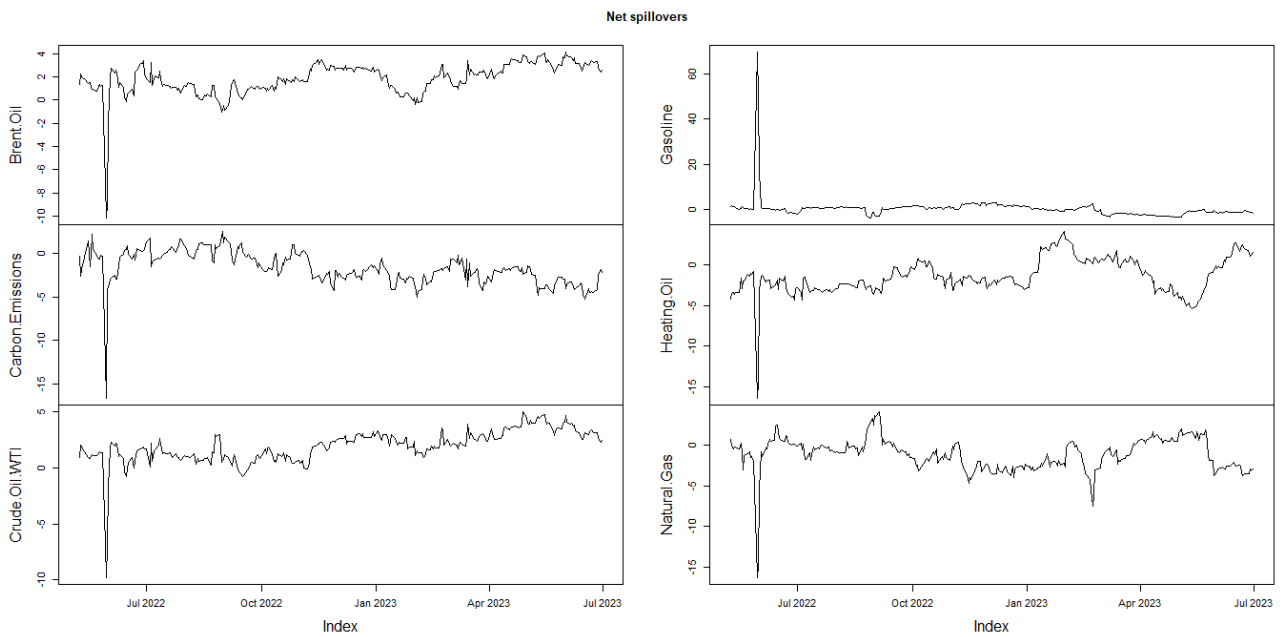


Figure 6: Net Spillovers in Energy market during Russia and Ukraine Crisis

5.0 Conclusion and Policy Implications

Our research paper investigates the dynamic return spillovers in the energy market during the Russia and Ukraine conflict, adopting the Diebold and Yilmaz (2012) spillover framework by analyzing the daily frequency data from 24th February 2022 to 30th June 2023. The findings of our research study confirm the existence of return spillovers in the energy market during the Russia and Ukraine conflict, revealing that the average total spillovers were 36.63%. The overall analysis indicates that the energy market experienced high total and directional return spillover during the beginning of the Russia and Ukraine conflict. Furthermore, the study highlighted that the fluctuations in the behavior of energy market return spillovers were significant, with the highest total spillover occurring during May 2022, reaching a spillover strength of 83.33. Additionally, Among the commodities, Brent Oil has been the major recipient of return spillovers, followed closely by Crude Oil during the Russia and Ukraine conflict. On the other hand, it was reported that carbon emissions and natural gas commodities are the lowest recipients of directional return spillovers in the energy market.

Furthermore, the correlation analysis provided valuable insights into the relationships among various energy commodities during the conflict. Brent Oil exhibited strong positive correlations with Crude Oil WTI. Conversely, Carbon Emissions showed weak positive correlations with Brent Oil, Crude Oil WTI, and Heating Oil and weak negative correlations with Natural Gas. These findings underscore the interconnections and interdependence of energy commodities during geopolitical tension and conflict. The strong correlations and significant return spillovers suggest that market participants closely monitored and reacted to the developments in the Russia and Ukraine crisis. The insights gained from this study have potential value for market participants, policymakers, and researchers seeking to comprehend the dynamics of the energy market amid geopolitical uncertainties.

The research findings and analysis have significant implications for various stakeholders in the energy market and beyond. Firstly, understanding the return spillover effects during geopolitical conflicts becomes crucial for effective risk management strategies. Market participants, including energy traders, investors, and financial institutions, can use the insights from this study to assess and manage potential risks associated with energy investments more effectively. By considering the interdependence between different energy commodities, they can develop robust risk management plans to mitigate adverse effects during periods of geopolitical tension. Secondly, investors can optimize their portfolios, reducing overall risk exposure and creating a more balanced and resilient investment approach. This becomes especially important during uncertain geopolitical events

impacting specific energy sectors. Furthermore, the insights from this study can inform the crafting of more effective energy policies during geopolitical turmoil.

Our research study was conducted based on daily frequency data. This relatively might now provide the in-depth dynamics of energy markets. Therefore, future research studies can be conducted on high-frequency datasets such as 5- 5-minute and 10-minute. Moreover, the research only covers the conflict between Russia and Ukraine. It did not account for potential impacts from other geopolitical events, regional conflicts, or policy decisions that can also influence the energy market. Considering a broader range of geopolitical factors in future analyses could enhance the model's explanatory power and provide a more holistic view of market dynamics during geopolitical tensions. Furthermore, researchers could explore advanced econometric techniques and time-series models to improve the accuracy of measuring spillover effects. Techniques like time-varying parameter models, copula-based approaches, or dynamic conditional correlations could provide valuable insights into spillover evolution over time. Finally, we also propose another recommendation that future research can systematically explore the impact on additional commodities or alternative energy sources, incorporating them into the analysis as data availability permits.

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