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MODELING WORLD NATURAL GAS AND CRUDE OIL TRADE NETWORKS

World energy security is sensitive to stable energy environment and geopolitics that depend on inter-regional energy trade strategies. However, this study uses the network connectedness measures of Diebold-Yilmaz to find the trade cooperation/competition preference for non-renewables' security development. To this end, the dynamic asymmetries of weighted spillover effects of natural gas and crude oil trade flow components are analyzed throughout world trade networks before- and after the sharp fall in crude oil prices. The results exhibit that natural gas and crude oil trade networks experience asymmetric- and time-varying behavior in response to transitory- vs. permanent components as well as positive- vs. negative shocks pre-and post- sharp fall in crude oil prices. Specifically, the natural gas and crude oil trade networks show a lesser degree of integration after 2014.

Moreover, the natural gas trade network represents more (less) weighted sensitivity to short-term fluctuations (long-term trend) than the crude oil trade network pre-and post- 2014. As the other comparative result, a higher (lower) degree of integration is detected in the crude oil trade network in response to the positive (negative) shocks compared to the natural gas trade network pre-and post- 2014. Therefore, a lower level of cooperation preference among regions is proposed in the natural gas and crude oil trade networks in response to a sharp fall in crude oil prices. Also, decisions about

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energy conservation, environmental protection, and protection of strategic resources can affect a region's natural gas and crude oil supply and demand security.

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1. INTRODUCTION

Natural gas has become a vital energy resource in climate change and energy supply security as a form of cleaner energy compared to coal and crude oil. Also, as a non-renewable strategic resource, crude oil plays a critical role in enabling basic human needs, including food, shelter, and transportation (Liu et al., 2020).

Based on the rule of comparative advantage and a high degree of specialization of the economies (Antweiler et al., 2001; Hummels et al., 2001), natural gas and crude oil have become considerable energy resources with a significant impact on international energy security and strategies (Ji et al., 2014) and economic development, military and political strategies (Wu & Chen, 2019) with dynamic relations of competition and substitution in various sectors (Renou-Maissant 1999; Serletis et al. 2011).

Specifically, the primary gas markets, including North America, Europe, and Asia, remain more regional than, for example, the oil market, and hence geopolitical considerations continue to play an important role. Thus, natural gas and crude oil participants' trading strategies are classified into cooperation and competition preference (Persson & Wilhelmsson, 2016; Jensen & Shin, 2014; An & Guan, 2017). Therefore, the world energy trade features are becoming increasingly important to understand (Managi & Kitamura, 2017).

In most recent studies, the crude oil trade relations have been investigated through complex network technic as a static approach. An et al. (2018) investigate the dependency network of international oil trade by focusing on its changes after the oil price drop and show that global oil trade relationships changed considerably after 2014. Moreover, the trade preferences of cooperation partners in crude oil, coal, natural gas, and international photovoltaic trade are explored by An and Guan (2017). They conclude that international photovoltaic trade involves much denser cooperation among countries than crude oil, coal, and natural gas. Managi and Kitamura (2017) characterize the effects of geographical restrictions on crude oil and petroleum trade partner selection. They reveal that restrictions on trade partner selection due to geographical resistance forces neighboring oil-importing countries to choose similar oil-exporting countries, and diversification in petroleum exporting countries reduces supply disruption risk for importing countries. Also, Dong et al. (2016) construct a complex network to explore the world crude oil trade features and evolution. Results exhibit that most countries have few trading nations, while only a minority has many trading partners. Furthermore, they show that few countries have the most trading partners, and simultaneously they are seen as important transit hubs.

The other related research group studies the role of U.S. technology improvements in energy markets. Fattouh et al. (2015) analyze the effect of the U.S. shale gas revolution on Qatar's position in the global natural gas market. They find that North America can compete with Qatar as North America's LNG export destinations are not limited to Europe or Asia at the time of export. They also find that large quantities of North American LNG exports would help to expand the spot market for natural gas. Moryadee et al. (2014) study the impact of U.S.' LNG exports on North American and global natural gas markets. They indicate that U.S.' local natural gas prices increase, while European and Asian natural gas prices fall due to large quantities of LNG exportation. Also, Gracceva and Zeniewski (2013) analyze the impact of the U.S. shale gas revolution on the regional distribution of natural gas- production, trade, demand, and prices by setting different scenarios for U.S.' shale gas development.

Regions[1] always need to observe the behavioral dynamics of world energy trade to make timely adjustments in their trade networks in response to the market fluctuations and uncertainties that can be fulfilled through spillover effects. Moreover, as a consequence of successive episodes of the economic and financial crisis, black swan events, geopolitical tensions, structural changes in the business cycle, and heterogeneous regions (Jammazi et al., 2014), as well as skewed and leptokurtic utilized variables (Bai & Lam, 2019), static models are not suitable for modeling natural gas and crude oil trade networks.

To the best of our knowledge, a few studies consider the spillover effects in energy trade analysis. Shirazi et al. (2020) analyze the crude oil trade network of Eastern Europe and Eurasia and show that the crude oil trade flow of Eastern Europe and Eurasia experiences net volatility transmission to Iran, Russia, and the U.S., respectively. In contrast, it is a net volatility receiver from Saudi Arabia. Moreover, risk spillover effects of the international commodities on maritime markets are determined by Li et al. (2020). They conclude that commodity markets exert different spillover effects on global and Chinese domestic maritime markets. They also show that the oil market is more efficient than other commodities

[1] North & Latin America, Asia Pacific, Eastern Europe & Eurasia, Western Europe, Africa and Middle East

without substitutes through the global dry cargo freight and tanker markets. Chen et al. (2020) study fluctuation characteristics and impact of critical events in crude oil maritime transportation systems and find that transportation lines possess long-term memory. Furthermore, the role of country, transportation risks, and crude oil prices are analyzed by Wallace et al. (2020) to handle financial risks in crude oil imports. They propose two-stage stochastic programming models and show that real financial risk is much higher than the importer might believe if physical risks are not considered.

Consequently, in light of the future of the natural gas and crude oil trade network is uncertain due to their applications, policy regulations, and whether traders in such energy markets are sensitive to their trade flow shocks and trends. Therefore, as one of the main gaps among existing studies, the main research question is to find the dynamic prioritization of cooperative behavior (e.g., avoiding regional and international antagonism, diversification of trade uncertainties, economies of scale, and a high degree of specialization) or competition preference (e.g., conservation and uncertainty protection based on power concentration) for natural gas and crude oil risk management in response to inter-regional trade flow shocks to mitigate the vulnerability of regional- and world energy security.

Accordingly, and as the contributions of this paper, pre-and post-2014, when crude oil prices fell sharply and based on OPEC regional grouping, e.g., North and Latin America, Asia Pacific, Eastern Europe, and Eurasia, Western Europe, Africa, and the Middle East, we use network connectedness measures of Diebold-Yilmaz (2016) to analyze dynamic asymmetries in weighted spillover effects and interdependence in natural gas and crude oil trade networks.

Specifically, as the empirical structure of this paper, first, the Hodrick-Prescott (1997) filter is applied to extract the stationary cyclical movements (short-term fluctuations) of natural gas, and crude oil trade flows as suggested by Ewing and Thompson (2007). Then, we analyze the asymmetric behavior of natural gas and crude oil trade networks pre-and post-2014 in response to transitory- vs. permanent shocks of the trade flows. Also, we explain the spillover effects through the negative- vs. positive shocks of natural gas and crude oil trade flows. Finally, we discuss the potential time-varying and asymmetric influence of natural gas and crude oil trade behavior throughout the networks.

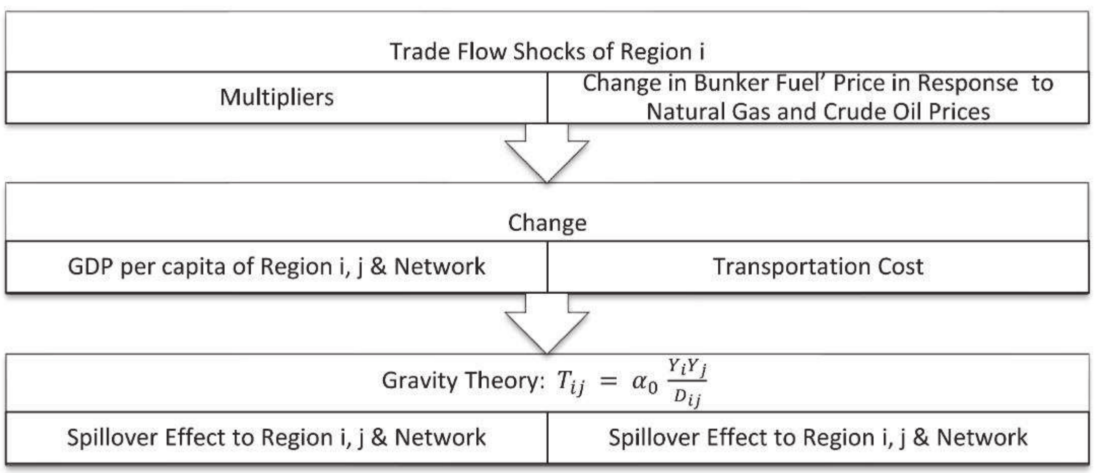
The main findings indicate that the natural gas trade network seems to be more sensitive than the crude oil trade network before and after the sharp oil price decline, which needs more focus on the cooperative behavior among regions to lessen natural gas supply and demand insecurity. Moreover, a sharp drop in crude oil prices may lead to a heterogeneous effect on natural gas and crude oil supply and demand security in different regions, depending on their specific weighted trade flows, energy reserves, production capacities, and geopolitics.

2. TRANSMISSION MECHANISM OF SPILLOVER EFFECTS ACROSS ENERGY TRADE NETWORK

Spillover effects across the natural gas and crude oil trade flows are transmitted through two different channels (Adland & Cullinane, 2006; Alizadeh & Nomikos, 2004; Glen & Martin, 2005; Poulakidas & Joutz, 2009), indicated by the following flow chart.

Fig. 1:

TRANSMISSION MECHANISM OF SPILLOVER EFFECTS ACROSS NATURAL GAS AND CRUDE OIL TRADE FLOWS



Note: T_{ij} is the trade flow from region i to region j, Y_i & Y_j are region i's GDP and region j's GDP, respectively, D_{ij} is their distance and α_0 is the constant[2]

The first channel is that shocks in natural gas and crude oil trade flows[3] (An et al., 2018) have a direct impact on GDP per capita of region i, j and the whole network, which leads to spillover effects across the natural gas and crude oil trade flows, based on gravity theory. The second channel is that shocks in natural gas and crude oil prices due to changes in their trade flow directly impact shipping companies' transportation costs and spillover effects through gravity theory.

[2] See Tsurumi et al, (2015) for review

[3] Trade flow is defined as sum of export and import

Therefore, the natural gas and crude oil trade shocks and supply and demand spillover effects are shifted between importing and exporting participants (Meng et al., 2018). It is believed that increasing reliance on imports exacerbates a region's sensitivity to the effects of natural gas and crude oil shocks as risks occur in the energy-importing process (Lacasse and Plourde, 1995; Biresselioglu et al., 2015; Biresselioglu et al., 2012). Specifically, natural gas and crude oil importers mention uncertainties regarding the secured supply process, whereas, for exporters, the main concern is highly reliable energy exports or durable demand from buyers that are needed for the domestic economic development.

3. MATERIALS AND METHODS

Network connectedness measures of Diebold-Yilmaz are the dynamic form of the most well-known and fundamental description of overall network topology[4] as a static approach commonly used in the previous energy trade network analysis (Managi & Kitamura 2017; Ji et al., 2014; among others). Also, the Diebold-Yilmaz (2016) methodology is based on a dynamic stationary VAR[5] model, which is consistent with the series of weighted trade flow components under consideration that seems to be stationary, skewed, leptokurtic, and correlated variables. Accordingly, we implement Diebold-Yilmaz's (2016) methodology (Shirazi et al. 2020; Onur Tas et al. 2018) using the logarithmic series of weighted[6] annual data of natural gas and crude oil trade flow by each region data for the period 1980–2019 from the OPEC database. Then, we calculate the weighted spillover effects by taking into account changes in the quantity of natural gas and crude oil trade flow caused by other regions to obtain natural gas and crude oil trade flow connectedness and coordination measures[7]. Moreover, moving average coefficients are of utmost importance in understanding dynamic links between variables. These coefficients allow dividing each variable's H-step-ahead forecast error variances into parts attributable to various system shocks. We follow Diebold-Yilmaz (2016) and implement the generalized orthogonalization approach of Koop et al. (1996) and Pesaran and Shin (1998) when estimating the parameters of the VAR and calculating variance

[4] See Diebold & Yilmaz (2016) for more details

[5] Vector Auto Regressive

[6] We weighted the natural gas and crude oil trade flow of all regions by dividing the total world natural gas and crude oil trade flow, respectively

[7] Alternatively, we do the estimations via absolute values of the trade flows, showing that both methods provide similar outcomes

decompositions. This approach is independent of the ordering of variables and accounts for correlated shocks.

Therefore, the forecast error variance decomposition for H-step ahead or variable j's contribution to the H-period-ahead generalized error variance of the variable i is as follows:

$$d_{ij}(H)=\frac{\sigma_{jj}^{-1}\sum_{h=0}^{H-1}\left(\acute{e}_i A_h \sum e_j\right)^2}{\sum_{h=0}^{H-1}(\acute{e}_i A_h \sum \acute{A}_h e_j)} \tag{1}$$

where σ_{jj} is the standard deviation of errors (ε_j), $\sum$ is the variance matrix of ε_j, and e_i, e_j are the selection column vectors with ith element unity and zeros elsewhere. $d_{ij}(H)$ is the fraction of the H-step-ahead error variance of i from shocks to j. In the generalized variance decomposition matrix, diagonals and off-diagonals present their own- (variable i to itself) and pairwise contributions (variable i to variable j), respectively. However, row sums in generalized variance decomposition matrices are not necessarily equal to 1, and thus each entry is normalized by the row sum as follows:

$$\widetilde{d_{ij}}(H)=\frac{d_{ij}(H)}{\sum_{j-1}^{N} d_{ij}(H)} \tag{2}$$

Diebold-Yilmaz (2016) define pairwise directional connectedness from j to i using $C_{i\leftarrow j}(H)=\widetilde{d_{ij}}(H)$. Accordingly, the total directional spillover effect is calculated to determine the coordination measures across the suggested variables. Hence, the net pairwise directional connectedness from j to i is:

$$\tilde{d}_{ij}^{net}(H)=C_{i\leftarrow j}(H)-C_{j\leftarrow i}(H) \tag{3}$$

Also, the directional spillover effect (connectedness measure) from others to i is:

$$C_{i\leftarrow o}(H)=\frac{\sum_{\substack{j=1\\ j\neq i}}^{N}\widetilde{d_{ij}}(H)}{\sum_{i,j=1}^{N}\widetilde{d_{ij}}(H)}\times 100=\frac{\sum_{\substack{j=1\\ j\neq i}}^{N}\widetilde{d_{ij}}(H)}{N}\times 100 \tag{4}$$

while the directional spillover effect from i to others is:

$$C_{o\leftarrow i}(H)=\frac{\sum_{\substack{i=1\\ j\neq i}}^{N}\widetilde{d_{ij}}(H)}{\sum_{i,j=1}^{N}\widetilde{d_{ij}}(H)}\times 100=\frac{\sum_{\substack{i=1\\ j\neq i}}^{N}\widetilde{d_{ij}}(H)}{N}\times 100 \tag{5}$$

Moreover, the net directional spillover effect is used to indicate whether one variable is a net shock- receiver or transmitter throughout the network, which is considered as:

$$C_i^{net}(H) = C_{o \leftarrow i}(H) - C_{i \leftarrow o}(H) \tag{6}$$

Finally, the spillover index (average total spillover), C (H), is calculated to show the degree of integration of the network:

$$C(H) = \frac{\sum_{\substack{i,j=1 \\ j \neq i}}^{N} d_{ij}(H)}{\sum_{i,j=1}^{N} d_{ij}(H)} \times 100 = \frac{\sum_{\substack{i,j=1 \\ j \neq i}}^{N} d_{ij}(H)}{N} \times 100 \tag{7}$$

where, $d_{ii}(H)$ is the uncertainty contribution of variable i to itself, $d_{ij}(H)$ is the uncertainty contribution of variable- j to i. The spillover index shows the average contribution of spillovers from shocks of all variables to the total forecast error variance. In brief, the net pairwise spillover effect identifies the region that plays a dominant role in shock transmission between two regions. The net total directional connectedness indicates the dominant region in shock transmission between regions, and the spillover index measures the degree of integration among all markets under consideration. Consequently, we can imply the trade strategy prioritization of the cooperation preference rather than competitive behavior as the network experiences a higher degree of integration and vice versa.

In addition to symmetric connectedness, we investigate two types of asymmetry in the natural gas and crude oil trade networks. Therefore, it is helpful to compare the asymmetric weighted spillover effects across the natural gas, and crude oil trade flows to undermine the negative impacts of unexpected events. For simplicity and based on Lau et al. (2019), we build positive- and negative connectedness networks as the increasing and decreasing decompositions of trade flows, respectively. The positive and negative series of natural gas and crude oil trade flow (iv_{jt}^{+}, iv_{jt}^{-}) are measured as follows:

$$iv_{jt}^{+} = \begin{Bmatrix} \sum_{k=1}^{t} \Delta iv_{ik}^{+} & \textit{if } \Delta iv_{ik} > 0 \\ 0 & \textit{otherwise} \end{Bmatrix}, \quad iv_{jt}^{-} = \begin{Bmatrix} \sum_{k=1}^{t} \Delta iv_{ik}^{-} & \textit{if } \Delta iv_{ik} < 0 \\ 0 & \textit{otherwise} \end{Bmatrix} \tag{8}$$

Then, the trade flow time series can be decomposed into permanent and transitory components. The permanent component is the long-term trend of the time series, which is interpreted to be its fair value and can be regarded as a process of a random walk with drift (Amihud & Mendelson, 1987). The transitory component represents short-term fluctuations from the trend, which may be caused by variables that do not enter the theory and thus have to be fitted empirically. Also, we use Hodrick–Prescott (1997) filter approach in this paper since our analysis is purely historical. However, we provide the asymmetric behavior of natural gas and crude oil trade flow networks in response to transitory- vs. permanent shocks of trade flow through the Hodrick–Prescott (1997) filter approach.

4. RESULTS

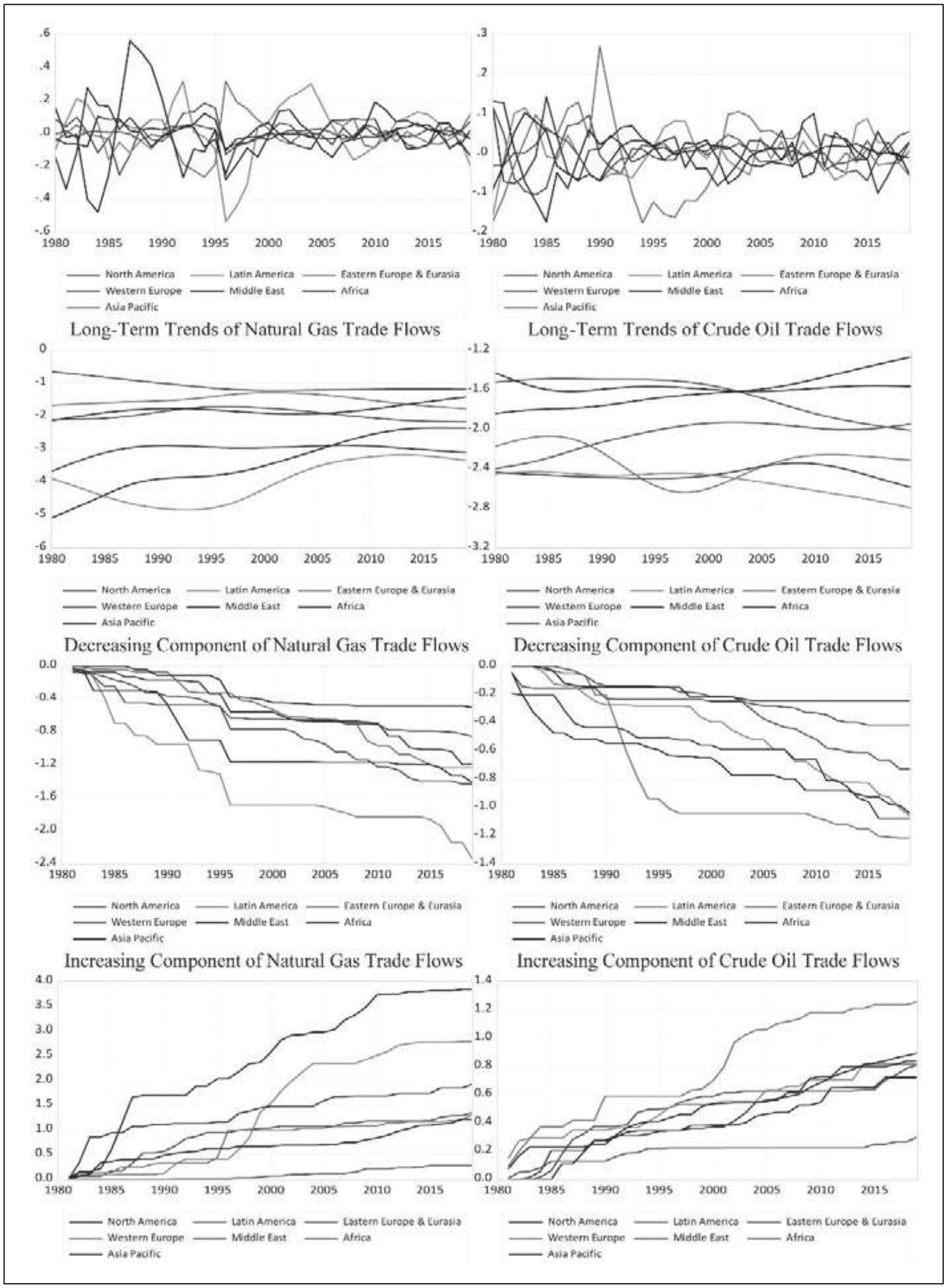
4.1 Stylized Facts, Summary of Descriptive Statistics, Unit Root Tests and Correlations

Fig. 2 shows that both decompositionsrelated to weighted natural gas and crude oil trade flow for North and Latin America, Asia Pacific, Eastern Europe, Eurasia, Western Europe, Africa, and the Middle East almost follow the same path with different magnitudes over the time period. Specifically, both natural gas and crude oil trade flows of all seven utilized regions indicate increasing long-term trends over time, whereas a flat slope has been found in recent years except for the Asia Pacific. Moreover, Western Europe and Latin America experience the highest and lowest levels of long-term trends in natural gas trade flows, while the levels of crude oil trends vary over the time period, respectively[8]. Also, the Asia Pacific and Latin America (the Asia Pacific and Eastern Europe and Eurasia) show the highest and lowest levels of decreasing component of natural gas (crude oil) trade flows in most of the period, while the Middle East and Western Europe (Eastern Europe and Eurasia and Western Europe) meet the most and least values of increasing component of natural gas (crude oil) trade flows in recent years.

[8] In 2017, nearly 50% of the global crude oil production was internationally traded (BP, 2018)

Fig. 2:

STYLIZED FACTS OF WEIGHTED NATURAL GAS AND CRUDE OIL TRADE FLOWS



Source: Authors' Calculations

Moreover, the unit root tests based on automatic bandwidth selection of Andrews (1991) and Newey & West (1994) support the conclusion that all suggested series of weighted trade flows are stationary at the 1% significance level. Also, overall, strong and moderate negative correlations exist among regional natural gas and crude oil trade flows, respectively. Specifically, the overall negative correlations are reasonable since the suggested variables are linked to their market shares in the weighted form. Furthermore, the suggested variables are identified as skewed and leptokurtic. Therefore, the Diebold-Yilmaz (2016) technic seems to be applicable in justifying the behavioral characteristics of natural gas and crude oil trade flow networks.

4.2 Asymmetric Spillover Effects in response to Transitory- vs. Permanent Shocks of Natural Gas and Crude Oil Trade Flows

We conclude a unilateral shock transmission when the sign of net spillover effect is positive and greater than one and, of course, the opposite around for unilateral shock receipt. Moreover, there would be a bidirectional spillover effect with the results lower than one in absolute values.

Based on table 1, the weighted spillover index (S.I) of transitory and permanent components is 42.8% and 57.3%, respectively, indicating a sizeable degree of integration across the natural gas trade flow network during the sample period. Therefore, the comparison results of the spillover index exhibit the strategy prioritization of cooperative behavior for the natural gas trade flow network in response to short-term fluctuations and permanent shocks across the regions under consideration due to high levels of network sensitivity.

Findings also reveal that North America, Africa, the Middle East, Latin America, and the Asia Pacific experience (-12.6), (-8), (-7.5), (-6.6), and (-5.1) percent of net total spillover in the natural gas trade network, respectively, showing they are net shock receivers from short-term fluctuations of natural gas trade flows. In contrast, Eastern Europe and Eurasia, and Western Europe face net shock transmission to the network with (38.2) and (1.7) percent, respectively. As an asymmetric behavior, Eastern Europe and Eurasia are just net shock transmitters to North and Latin America and the Asia Pacific in response to permanent shocks. Furthermore, there is a unilateral spillover effect from Western Europe to all areas except Africa and North America just to the Middle East. Findings also express that Asia Pacific, Africa, and North America encounter net shock receivers from permanent natural gas trade flows shocks, whereas Western Europe, Eastern Europe, Eurasia, and the Middle East experience net shock transmission to the network, respectively.

In the following, Table 2 presents the matrix of transitory- vs. permanent components of spillover effect among crude oil trade flows. Following the results, the weighted spillover index (S.I) of short-term fluctuations of crude oil trade flows is 30.7%, indicating the relative importance of concentration for reasoning shock transmission outside the network. Also, the degree of integration for the long-term component of crude oil trade flows is 74.7% over the time period, attracting more focus on internal affecting factors to understand shock transmission channels throughout the network better.

Hence, the comparison results of the spillover index exhibit the prioritization of cooperation (competition) based trade strategies in the behavior of crude oil trade network in response to the permanent (transitory) component of trade flows that take place across the regions. Therefore, more focus on crude oil reserves, production capacities, and geopolitics as the external affecting factors may lead to lower short-term fluctuations of crude oil trade flows and less economic vulnerability across the regions under consideration.

The long-term component network of crude oil trade flow indicates net shock receipt from all areas except for North- and Latin America. Findings also reveal that Western Europe, Latin America, Asia Pacific, Africa, Eastern Europe, and Eurasia are net shock receivers from short-term fluctuations of crude oil trade flows, whereas the Middle East and North America are net shock transmitters to the network. Moreover, Latin America, North America, and the Asia Pacific are net shock receivers from the long-term component of crude oil trade flows, while Eastern Europe and Eurasia, Western Europe, Africa, and the Middle East experience net shock transmission to the network, respectively. Hence, the results expose asymmetric behavior of natural gas, and crude oil trade flows in response to transitory- vs. permanent shocks with evidence of a higher degree of integration among long-term components, which may need more concentration on cooperation trade strategies due to greater trade sensitivity across the regions.

Table 1:

ASYMMETRIC BEHAVIOUR OF NATURAL GAS TRADE NETWORK IN RESPONSE TO TRANSITORY- VS. PERMANENT SHOCKS OF TRADE FLOWS

Weighted Spillover Effects of Natural Gas Trade Flow Network in response to Transitory Shocks of Trade Flows (No. Obs: 40)								
Region	North America	Latin America	Eastern Europe[9]	Western Europe	Middle East	Africa	Asia Pacific	from Others
North America	58.2	2.5	26.3	5.7	0.1	3.0	4.2	41.8
Latin America	2.2	50.2	16.5	13.3	1.6	0.6	15.7	49.8
Eastern Europe	14.8	10.7	32.8	22.4	1.8	3.0	14.4	67.2
Western Europe	4.2	11.2	29.1	42.5	2.4	1.3	9.3	57.5
Middle East	0.2	2.7	4.7	4.8	85.2	0.1	2.2	14.8
Africa	4.4	1.0	7.7	2.5	0.1	83.3	1.1	16.7
Asia Pacific	3.5	15.0	21.2	10.4	1.3	0.6	48.0	52.0
Contribution to Others	29.2	43.2	105.4	59.2	7.3	8.7	46.9	299.8
Net Total Spillover	-12.6	-6.6	38.2	1.7	-7.5	-8	-5.1	S.I: 42.8%
Weighted Spillover Effects of Natural Gas Trade Flow Network in response to Permanent Shocks of Trade Flows (No. Obs: 40)								
Region	North America	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Asia Pacific	from Others
North America	41.7	9.0	8.8	22.4	16.6	0.2	1.4	58.3
Latin America	7.6	35.4	18.1	27.1	2.3	2.0	7.5	64.6
Eastern Europe	6.9	16.7	32.7	23.7	0.9	0.1	19.0	67.3
Western Europe	15.5	22.1	20.9	28.9	7.0	0.0	5.5	71.1
Middle East	18.2	2.9	1.2	11.0	45.6	20.8	0.3	54.4
Africa	0.3	3.7	0.2	0.0	29.8	65.4	0.5	34.6
Asia Pacific	1.6	10.4	28.6	9.4	0.3	0.4	49.3	50.7
Contribution to Others	50.1	64.9	77.8	93.5	57.0	23.5	34.1	400.9
Net Total Spillover	-8.2	0.3	10.5	22.4	2.6	-11.1	-16.6	S.I: 57.3%

Source: Authors' Calculations

[9] Eastern Europe and Eurasia

Table 2:

ASYMMETRIC BEHAVIOUR OF CRUDE OIL TRADE NETWORK IN RESPONSE TO TRANSITORY- VS. PERMANENT SHOCKS OF TRADE FLOWS

Weighted Spillover Effects of Crude Oil Trade Flow Network in response to Transitory Shocks of Trade Flows (No. Obs: 40)								
Region	North America	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Asia Pacific	From Others
North America	60.0	10.7	10.4	0.2	6.5	0.4	11.7	40.0
Latin America	12.7	71.3	3.8	0.1	11.3	0.2	0.7	28.7
Eastern Europe	11.0	3.4	63.4	0.7	17.4	2.7	1.3	36.6
Western Europe	0.3	0.1	0.9	78.6	19.8	0.2	0.2	21.4
Middle East	5.4	7.9	13.8	12.6	50.1	6.3	3.9	49.9
Africa	0.6	0.2	3.6	0.2	10.6	84.7	0.0	15.3
Asia Pacific	15.0	0.7	1.6	0.2	5.9	0.0	76.6	23.4
Contribution to others	45.0	23.1	34.1	14.1	71.4	9.8	17.8	215.2
Net Total Spillover	5	-5.6	-2.5	-7.3	21.5	-5.5	-5.6	S.I: 30.7%
Weighted Spillover Effects of Crude Oil Trade Flow Network in response to Permanent Shocks of Trade Flows (No. Obs: 40)								
Region	North America	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Asia Pacific	From Others
North America	26.6	2.1	18.0	10.0	21.4	18.6	3.3	73.4
Latin America	3.4	43.2	14.4	13.1	4.1	6.0	15.9	56.8
Eastern Europe	12.9	6.3	18.9	16.6	15.9	17.0	12.4	81.1
Western Europe	7.8	6.3	18.1	20.7	12.8	15.9	18.3	79.3
Middle East	17.3	2.0	18.0	13.3	21.5	20.6	7.3	78.5
Africa	14.1	2.8	18.0	15.4	19.3	20.2	10.1	79.8
Asia Pacific	3.2	9.5	16.9	22.8	8.8	13.0	25.8	74.2
Contribution to others	58.7	29.0	103.6	91.2	82.3	91.0	67.3	523.0
Net Total Spillover	-14.7	-27.8	22.5	11.9	3.8	11.2	-6.9	S.I: 74.7%

Source: Authors' Calculations

4.3 Asymmetric Spillover Effects in response to Positive- vs. Negative Shocks in Natural Gas and Crude Oil Trade Flows

Based on table 3, the weighted spillover index (S.I) of positive and negative shocks related to natural gas trade flows is 13.1% and 44.8%, respectively. As a result, and based on the sensitivity levels of the networks, the competitive (cooperative) behavior of the natural gas trade flow network is preferred in response to positive (negative) shocks of trade flows across the utilized regions.

Findings also reveal that the Middle East and the Asia Pacific are net shock receivers and transmitters in response to the positive shocks of natural gas trade flow, respectively, and neither dominant nor recessive role for the rest of the areas.

Moreover, the Middle East, Africa, Eastern Europe, and Eurasia, North- and Latin America are net shock receivers from the negative component of natural gas trade flows. In contrast, the Asia Pacific and Western Europe are net shock transmitters to the network, respectively.

Table 3:

ASYMMETRIC BEHAVIOUR OF NATURAL GAS TRADE NETWORK IN RESPONSE TO INCREASING- VS. DECREASING COMPONENTS OF TRADE FLOWS

Weighted Spillover Effects of Natural Gas Trade Flow Network in response to Positive Shocks of Trade Flows (No. Obs: 39)								
Region	North America	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Asia Pacific	From Others
North America	90.1	0.1	8.6	0.7	0.1	0.2	0.2	9.9
Latin America	0.1	88.5	2.8	0.7	0.6	7.3	0.1	11.5
Eastern Europe	8.3	2.7	87.0	0.8	0.1	0.7	0.4	13.0
Western Europe	0.7	0.7	0.8	94.1	0.0	0.2	3.4	5.9
Middle East	0.1	0.6	0.1	0.0	89.6	1.7	8.0	10.4
Africa	0.2	6.6	0.7	0.2	1.5	79.9	11.0	20.1
Asia Pacific	0.2	0.1	0.4	2.8	7.0	10.8	78.7	21.3
Contribution to others	9.5	10.8	13.4	5.1	9.3	21.0	23.0	92.0
Net Total Spillover	-0.4	-0.7	0.4	0.8	-1.1	0.9	1.7	S.I: 13.1%
Weighted Spillover Effects of Natural Gas Trade Flow Network in response to Negative Shocks of Trade Flows (No. Obs: 39)								
Region	North America	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Asia Pacific	From Others
North America	53.6	8.3	0.8	7.0	2.5	9.8	18.0	46.4
Latin America	7.9	51.3	4.9	8.9	5.2	2.1	19.6	48.7
Eastern Europe	1.2	7.6	79.1	3.0	7.0	0.4	1.7	20.9
Western Europe	5.5	7.3	1.6	41.9	4.2	15.5	24.0	58.1
Middle East	3.3	7.0	6.1	6.9	69.1	3.7	3.9	30.9
Africa	9.6	2.2	0.3	19.6	2.8	53.0	12.5	47.0
Asia Pacific	12.9	14.7	0.8	22.0	2.2	9.1	38.4	61.6
Contribution to others	40.5	47.0	14.5	67.4	23.9	40.5	79.8	313.6
Net Total Spillover	-5.9	-1.7	-6.4	9.3	-7	-6.5	18.2	S.I: 44.8%

Source: Authors' Calculations

Following table 4, the weighted degree of integration (S.I) related to positive- and negative shocks of crude oil trade flows gets to 19.1% and 18.9%, respectively. Therefore, the comparison results of the weighted spillover index show the prioritization of competitive behavior of crude oil trade flow network in response to both positive- and negative shocks occur across the regions under consideration since the networks experience low levels of weighted sensitivity.

Also, North America, Western Europe, and Africa are net shock receivers from the positive component of crude oil trade flows, whereas Eastern Europe, Eurasia, and the Middle East show net shock transmission to the network and passive for the rest of the regions.

Moreover, Eastern Europe and Eurasia, North America, and Western Europe are net shock receivers from negative components related to crude oil trade flows, whereas the Middle East acts as a net shock transmitter to the network and neither dominant nor recessive role for the rest of areas under consideration.

Table 4:

ASYMMETRIC BEHAVIOUR OF CRUDE OIL TRADE NETWORK IN RESPONSE TO INCREASING- VS. DECREASING COMPONENTS OF TRADE FLOWS

Weighted Spillover Effects of Crude Oil Trade Flow Network in response to Positive Shocks of Trade Flows (No. Obs: 39)								
Region	North America	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Asia Pacific	From Others
North America	86.2	3.0	0.0	0.1	6.7	0.7	3.4	13.8
Latin America	2.6	76.2	0.3	0.6	11.0	0.6	8.7	23.8
Eastern Europe	0.0	0.3	75.5	11.2	7.4	1.0	4.7	24.5
Western Europe	0.1	0.6	12.5	84.5	0.2	1.2	0.8	15.5
Middle East	5.8	10.9	7.4	0.2	75.4	0.0	0.2	24.6
Africa	0.7	0.7	1.2	1.3	0.0	90.6	5.5	9.4
Asia Pacific	3.0	8.9	4.8	0.8	0.2	4.7	77.6	22.4
Contribution to others	12.3	24.4	26.2	14.1	25.6	8.2	23.3	134.0
Net Total Spillover	-1.5	0.6	1.7	-1.4	1	-1.2	0.9	S.I: 19.1%
Weighted Spillover Effects of Crude Oil Trade Flow Network in response to Negative Shocks of Trade Flows (No. Obs: 39)								
Region	North America	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Asia Pacific	From Others
North America	88.6	5.1	0.5	0.2	5.5	0.0	0.0	11.4
Latin America	4.8	83.2	0.0	2.0	2.2	0.9	6.9	16.8
Eastern Europe	0.5	0.0	81.2	0.3	14.9	2.4	0.6	18.8
Western Europe	0.2	2.1	0.3	86.2	4.0	4.2	3.1	13.8
Middle East	4.3	1.9	12.7	3.2	69.4	3.3	5.1	30.6
Africa	0.0	0.9	2.4	4.0	3.9	81.5	7.3	18.5
Asia Pacific	0.0	6.4	0.6	2.8	5.7	6.9	77.6	22.4
Contribution to others	9.8	16.3	16.6	12.4	36.3	17.8	23.0	132.2
Net Total Spillover	-1.6	-0.5	-2.2	-1.4	5.7	-0.7	0.6	S.I: 18.9%

Source: Authors' Calculations

4.4 Time-Varying Behaviour of Natural Gas & Crude Oil Trade Network in response to Components of Trade Flows

Based on table 5, the natural gas trade network seems to be more sensitive than the crude oil trade network before and after a sharp oil price decline, which needs more focus on the cooperative behavior among regions to lessen natural gas supply and demand insecurity.

Also, the weighted connectedness behavior of natural gas trade flows indicates less vulnerability for North- and Latin America, Western Europe, Middle East, and Africa after 2014, when crude oil prices fell sharply. Moreover, Eastern Europe and Eurasia meet no change in the position, whereas the Asia Pacific becomes passive after 2014.

On the other hand, the crude oil trade network shows that the Middle East acts more effectively over the network after 2014 and opposite Eastern Europe and Eurasia. Moreover, North America, Africa, and the Asia Pacific exhibit less vulnerability, whereas Latin America and Western Europe experience more vulnerability after the sharp drop in crude oil prices.

It is also worth noting that the economy of these parts of the world is heterogeneous through levels of vulnerability and effectiveness following the suggested types of natural gas and crude oil trade flow shocks and trends throughout the world trade network. Consequently, a sharp drop in crude oil prices may lead to a heterogeneous effect on natural gas and crude oil supply and demand security in different regions, depending on their specific weighted trade flows, energy reserves, production capacities, and geopolitics. For instance, Eastern Europe and Eurasia, and Western Europe play as affecting regions in response to transitory- and permanent shocks of natural gas trade flows across world network before and after 2014, whereas they are affected regions in reaction to short-term fluctuations of crude oil trade flow and dominant during permanent shocks of trade flows.

Furthermore, North America and Africa are net shock receivers in response to transitory- and permanent shocks of natural gas trade flows pre-and post- 2014. Also, Asia Pacific shows asymmetric behavior in reaction to transitory and permanent shocks of natural gas and crude oil trade flows. The Middle East plays a dominant role in response to transitory- and permanent shocks of crude oil trade flows before and after the sharp fall in prices, whereas North America is dominant and recessive in the short- and long-term, respectively.

Findings also indicate asymmetric behavior in natural gas and crude oil trade flow networks when positive and negative shocks are considered. Besides, there is no evidence of a recessive position for Asia pacific when positive and negative shocks happen in natural gas and crude oil trade flows before- and after 2014 and the opposite results for North America with more levels of net total spillover effect in response to negative shocks of natural gas are detected. Furthermore, Eastern Europe and Eurasia indicate a recessive role when negative shocks occur in natural gas and crude oil trade flows pre-and post- 2014. In addition, Middle East acts as a dominant role in response to both decreasing and increasing components of crude oil trade flows, while heterogeneous behavior is determined for the rest of the regions throughout the crude oil trade networks.

Additionally, the higher (lower) level of spillover index in the natural gas trade network in comparison with crude oil trade network in response to the transitory (permanent) component represents more (less) weighted sensitivity to short-term fluctuations (long-term trend) pre-and post- 2014. More specifically, the weighted spillover index of natural gas and crude oil trade networks shows a lesser degree of integration after 2014, indicating a lower level of cooperation preference among regions due to the sharp fall in crude oil prices. As the other comparative result, the higher (lower) degree of integration in the crude oil trade network than the natural gas trade network is detected in response to the positive (negative) shocks pre-and post- 2014.

Consequently, decisions about energy conservation, environmental protection, and protection of strategic resources can also affect a region's natural gas and crude oil supply and demand security.

Table 5:

COMPARISON RESULTS OF TIME-VARYING ASYMMETRIC NATURAL GAS & CRUDE OIL TRADE NETWORKS

Asymmetric Behaviour of Trade Flow Network in Response to Overall Trade Flow Shocks								
Net Total Spillover	North America	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Asia Pacific	S.I
Natural Gas (1980-2019)	-11.5	-7.9	38.8	-6.5	-3.1	-9.1	-0.7	40.0%
Natural Gas (1980-2013)	-12.2	-9.7	38.5	-7	-2.3	-10.8	3.5	42.3%
Crude Oil (1980-2019)	0.3	-5.8	4.3	-5.8	14.3	-2.6	-4.6	31.5%
Crude Oil (1980-2013)	-3	-3.7	14.1	-4.3	7	-4.3	-5.8	30.9%
Asymmetric Behaviour of Natural Gas Trade Flow Network in response to Transitory- vs. Permanent Shocks of Trade Flows								
Net Total Spillover	North America	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Asia Pacific	S.I
Cycle (1980-2019)	-12.6	-6.6	38.2	1.7	-7.5	-8	-5.1	42.8%
Cycle (1980-2013)	-12	-11.5	37.4	6.9	-8.1	-11	-1.8	46.8%
Trend (1980-2019)	-8.2	0.3	10.5	22.4	2.6	-11.1	-16.6	57.3%
Trend (1980-2013)	-11	-7.6	12.7	11.1	-4.9	-14.3	14.1	69%
Asymmetric Behaviour of Crude Oil Trade Flow Network in response to Transitory- vs. Permanent Shocks of Trade Flows								
Net Total Spillover	North America	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Asia Pacific	S.I
Cycle (1980-2019)	5	-5.6	-2.5	-7.3	21.5	-5.5	-5.6	30.7%
Cycle (1980-2013)	8.9	-7.5	-3.8	-6.6	20.3	-5.2	-6.1	31%
Trend (1980-2019)	-14.7	-27.8	22.5	11.9	3.8	11.2	-6.9	74.7%
Trend (1980-2013)	-4.2	-24.6	10.2	4.8	4.5	4.9	4.4	82%

Asymmetric Behaviour of Natural Gas Trade Flow Network in response to Positive- vs. Negative Shocks of Trade Flows								
Net Total Spillover	North America	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Asia Pacific	S.I
Positive Shocks (1980-2019)	-0.4	-0.7	0.4	0.8	-1.1	0.9	1.7	13.1%
Positive Shocks (1980-2013)	-0.5	-0.2	0.4	-0.7	-0.9	0.5	1.4	14.6%
Negative Shocks (1980-2019)	-5.9	-1.7	-6.4	9.3	-7	-6.5	18.2	44.8%
Negative Shocks (1980-2013)	-5.4	2.5	-9	8.7	-8.1	-4.3	15.6	51.6%
Asymmetric Behaviour of Crude Oil Trade Flow Network in response to Positive- vs. Negative Shocks of Trade Flows								
Net Total Spillover	North America	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Asia Pacific	S.I
Positive Shocks (1980-2019)	-1.5	0.6	1.7	-1.4	1	-1.2	0.9	19.1%
Positive Shocks (1980-2013)	-1.9	1	0.9	0.2	0.2	-2	1.8	24.7%
Negative Shocks (1980-2019)	-1.6	-0.5	-2.2	-1.4	5.7	-0.7	0.6	18.9%
Negative Shocks (1980-2013)	-1	-1.8	-2.6	-0.7	5.7	-2.2	2.6	18.6%

Source: Authors' Calculations

5. CONCLUSION AND POLICY IMPLICATION

While the energy market directly affects the economy, natural gas and crude oil trade strategies can influence geopolitics and can be utilized as tools to influence other regions. Accordingly, the main research contribution is to determine the dynamic prioritization of cooperative behavior or competition preference for natural gas and crude oil in response to the inter-regional trade flow shocks pre-and post- sharp fall in crude oil prices to mitigate the vulnerability of regional energy security. In light of cooperative/competitive behavior in world energy trade and based on OPEC regional grouping during 1980-2019, this paper provides new evidence of dynamic and asymmetric weighted spillover effects across the regional natural gas, and crude oil trade flows using the network connectedness measures of Diebold-Yilmaz (2016). The empirical results indicate that both networks indicate a sizeable degree of integration following the permanent shocks compared to short-term fluctuations of the trade flows. Also, the natural gas and crude oil trade networks show a lesser degree of integration after 2014. Moreover, the natural gas trade network represents more (less) sensitivity to short-term fluctuations (long-term trend) than the crude oil trade network before pre-and post- 2014. Therefore, the most important policy implications are as follows:

- Trade cooperation preference in natural gas trade network in response to both transitory- and permanent trade flow shocks
- Priority of competitive behavior (cooperation preference) in crude oil trade network in reaction to transitory (permanent) trade flow shocks
- The preference ordering of cooperation (competition) based trade strategies in natural gas trade network in response to negative (positive) shocks of natural gas trade flows
- The preference ordering of competition-based trade strategies in crude oil trade network in reaction to the positive and negative trade flow shocks
- The lower level of cooperation preference among regions in the natural gas and crude oil trade networks in response to a sharp fall in crude oil prices

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MODELIRANJE TRGOVINSKIH MREŽE PRIRODNOG PLINA I SIROVE NAFTE

Sažetak

Energetska sigurnost osjetljiva je na stabilnost okruženja i geopolitiku koja ovisi o među regionalnim energetskim trgovinskim strategijama. U ovom radu koristimo Diebold-Yilmaz mjeru povezanosti mreža kako bi utvrdili postojanje preferencije cooperacije/konkurencije za neobnovljive resurse. U ovu svrhu analiziramo dinamičku asimetričnost vaganog efekt prelijevanja komponenti trgovinskih tokova prirodnog plina i sirove nafte kroz svjetske trgovinske tokove prije i poslije oštrih padova cijene sirove nafte. Rezultati pokazuju da trgovinske mreže za prirodni plin i sirovu naftu odlikuje asimetričan i vremenski varirajuće ponašanje kao odgovor na transitorne u odnosu na permanentne komponente, kao i pozitivne u odnosu na negativne šokove prije i poslije oštrih padova cijene sirove nafte. Također, trgovinske mreže prirodnog plina i sirove nafte odražavaju nižu razinu integracije nakon 2014.

Trgovinske mreže prirodnog plina predstavljaju višu (nižu) vaganu osjetljivost na kratkoročne fluktuacije (dugoročni trend) od trgovinskih mreža sirove nafte prije i nakon 2014. Viši (niži) stupanj integracije detektiran je za trgovinske mreže sirove nafte kao odgovor na pozitivne (negativne) šokove u odnosu na trgovinske mreže za prirodni plin prije i nakon 2014. Prema tome, niža preferencija kooperacije među regijama sugerira se za trgovinske mreže prirodnog plina i sirove nafte kao odgovor na oštar pad cijene sirove nafte. Također, odluke o smanjenju energentske intenzivnosti, očuvanju okoliša i zaštiti strateških resursa mogu utjecati na sigurnost ponude i potražnje za prirodnim plinom i sirovom naftoma.

Ključne riječi: Strategija trgovanja energijom, asimetrični efekti prelijevanja, dinamička povezanost mreža