Networking through International Energy Organizations: Comparison by Trade Type

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INTRODUCTION

This study investigates differences regarding international energy cooperation among countries by energy trade type. In particular, it classifies 49 major oil and natural gas trading countries into exporting, importing, and balanced countries (i.e., remarkable countries in both export and import), and compares two network characteristics of each group within a network formed through participation in 28 international energy organizations. The analysis results confirm that both the importing and balanced groups have higher values for both degree and power centrality indices compared to the exporting group. However, there is no statistically significant difference between the importing group and the balanced one.

The results indicate that countries having considerable imports occupy more central positions with more partners, which increases their network influence. In other words, countries that are active oil and natural gas importers, regardless of their exports, are more active participants in international energy organizations than are countries that focus only on exports. One reason for this distinction is the lower energy bargaining power of importers. This study offers the expectation that exporting countries participate in more international energy organizations to compensate for their decreasing bargaining power.

The distinction between energy importing and exporting countries is a basic method of classifying countries. In particular, several studies explain the characteristics of crude oil (i.e., a representative source in energy trade) importing and exporting countries. For oil exporting countries, the relationships among energy consumption and other factors such as economic growth and export diversification have been studied [1-3]. For oil importing countries, vulnerability to oil supply and relevant risks are the primary issues considered in the literature [4,5]. Moreover, the effects of oil price volatility on the stock markets have been widely researched for both types of countries [6,7]. Energy importing and exporting countries tend to participate in distinct international energy organizations (e.g., the International Energy Agency versus the Organization of the Petroleum Export Countries). However, relevant research about their differences in international energy cooperation has been limited.

The purpose of our study is to compare the network characteristics of energy importing and exporting countries in their networks formed through participation in international energy organizations. We suggest how the participation in these two groups evolves. The contributions of this study are:

- It expands the understanding of international energy cooperation among countries by deriving a network of major energy trade countries formed through their participation in international energy organizations.
- It demonstrates a significant difference in energy cooperation between energy importing and exporting countries by comparing the distinct network characteristics each group holds within the network.
- It explains a cause for the difference between the two groups and presents a future direction for network change.

This article describes our study and is organized as follows. We initially explain the meaning and influence of the country network formed through participation in international organizations. Next, we derive the network formed by major energy trade countries through their participation in international energy organizations and reconfigure the derived network by presenting significant links. Then, we classify the countries in three groups by trade patterns and compare the network characteristics of each group within the reconfigured network. Finally, we explain the results of the comparison and present our conclusions.

COUNTRY NETWORKS

Participation in the Asia Infrastructure Investment Bank (AIIB) was established in January 2016. Prior to its launch, participation by western countries posed a dilemma [8]. Some objected to its being the first international financial institution led by China, emphasizing that it would lead to loss of their vested interests within global governance. Others favored participation, believing that cooperation with China would offer advantages and that non-member countries would be alienated from Asia's large infrastructure construction markets. However, the confrontation between the two groups ended as the United Kingdom became the first Western nation to join the AIIB. The balance quickly shifted after France, Germany, Italy, and the Netherlands joined. This new organization listed 57 countries as founding members. This example shows that membership in an international organization likely has more than only symbolic meaning of participation to international meetings.

Being a member of an international organization provides another meaningful consequence—members are connected through their common affiliation to the organization and form a network [9]. Likewise, member countries of an international organization are linked through the common affiliation to the organization and form a network [10]. These country networks have been extensively studied. While early studies simply explained the networks with existing theories recent ones have addressed international relations by exploring a more complex reality [11]. Countries holding a better position within a network formed through participation in international organizations could establish discussion agendas, subsequently formulating policies favorable to them [12]. Hafner-Burton and Montgomery have shown that the characteristics of each country in a network formed through participation in international organizations significantly impact international disputes and their consequences [10]. The impact of networks formed through participation in international organizations on another network (e.g., actual trade volume network) has also been explained [13]. While energy is a critical factor in international relations, and international energy organizations have active roles, research about international energy organizations and their networks has been limited. Next, existing networks are derived and analyzed.

METHODOLGIES

This study assumes that member countries in an international energy organization are linked to one another by their common affiliation and form a network [10]. To identify international energy organizations, we referred to the "Survey of G20 countries: gaps and duplication in the existing mandates and work plans of international energy organizations" approved by the G20 in 2014 [14]. Among the international energy organizations considered in our survey, we excluded the United Nations Framework Convention on Climate Change (UNFCCC), which has most of the world's countries as members, and the International Atomic Energy Agency (IAEA) with about 170 members. Also excluded were organizations whose membership is not clearly identified, such as the International Confederation of Energy Regulators (ICER) and the World Energy Forum (WEF).

Network Identification

Our study addresses 28 organizations (see Table 1). However, since the number of countries reached 142, it was difficult to draw meaningful implications about energy trading or cooperation among them. Therefore, only major countries engaged in energy trading were included in the analysis. Rather than addressing all energy sources, we focused on oil and natural gas, which account for about 75% of the world energy trade. We chose the top 20 countries in both exports and imports of oil and natural gas for analysis (see Table 2) and 49 countries were included in this study after excluding redundancies.

The configuration of the network of our 49 major countries, formed through their memberships in the 28 international energy organizations indicates that all countries actively participate in the organizations. Each country is connected to most of the other 48 countries. The average number of other actors with which any one actor is connected, called the average number of *degrees*, is 42.4. The *density*, measured as the number of actual connections between two actors over the number of possible connections, is 0.94, or almost 1, meaning nearly perfect connectivity within the network.

Centralization, a measure of the degree to which a network is concentrated in its center, decreases when the centrality of each actor becomes similar and increases when the variance of actors' centrality increases. The centralization value for our network is 0.06, or approximately 0, defining a completely dispersed network. Freeman's study refers to measurement, as shown in Equation 1 [15]. $Cx(p_i)$ is the centrality value of the *i*-th actor and $Cx(p^*)$ is the value of the most central actor in the network. The numerator of this index is the sum of differences

Table 1.
International energy organizations.

	International Energy Organizations
1	Organization of the Petroleum Exporting Countries (OPEC)
2	Gas Exporting Countries Forum (GECF)
3	EU Energy Initiative Partnership Dialogue Facility (EUEI PDF)
4	OPEC Fund for International Development
5	ASEAN Center for Energy
6	Latin American Energy Organization
7	European Association for the Promotion of Cogeneration (EAPC)
8	Energy and Climate Partnership of the Americas (ECPA)
9	International Energy Agency (IEA)
10	International Energy Forum (IEF)
11	International Gas Union (IGU)
12	International Partnership on Energy Efficiency Cooperation (IPEEC)
13	International Renewable Energy Agency (IRENA)
14	Clean Energy Ministerial (CEM)
15	Carbon Sequestration Leadership Forum (CSLF)
16	World Energy Council (WEC)
17	Energy Working Group, Asia-Pacific Economic Cooperation (APEC)
18	Asia Pacific Energy Research Centre (APERC)
19	Energy Cooperation Task Force, East Asia Summit (EAS)
20	Economic Research Institute for ASEAN (ERIA) and East Asia
21	Major Economies Forum on Energy and Climate (MEFEC)
22	World Petroleum Council (WPC)
23	Renewable Energy and Energy Efficiency Partnership (REEEP)
24	Global Carbon Capture and Storage Institute
25	Global Bioenergy Partnership (GBEP)
26	Renewables Club
27	Energy Charter Treaty (ECT)
28	Energy Regulators Regional Association (ERRA)

between the centrality value of the most central actor and the centrality values of the other actors in the network. The denominator is the maximum value of the sum which a network of the same number of actors might have.

$$C_x = [\sum N_{i=1} C_x(p_x) - C_x(p_i)] \div [\max \sum N_{i=1} C_x(p_x) - C_x(p_i)] \quad (1)$$

Table 2.
Major oil and natural gas trading countries.

Top 20 Oil Exporting Countries	Top 20 Oil Importing Countries	Top 20 Gas Exporting Countries	Top 20 Gas Importing Countries
Saudi Arabia	USA	Russia	Germany
Russia	China	Canada	Japan
Iran	India	Norway	Italy
Iraq	Japan	Algeria	United Kingdom
Nigeria	Republic of Korea	Netherlands	Republic of Korea
United Arab Emirates	Germany	Turkmenistan	France
Angola	Italy	Qatar	USA
Venezuela	France	Indonesia	Russia
Norway	Netherlands	Malaysia	Turkey
Canada	Singapore	USA	Spain
Mexico	Spain	Nigeria	China
Kazakhstan	United Kingdom	Australia	Ukraine
Kuwait	Thailand	Trinidad & Tobago	Netherlands
Qatar	Canada	Egypt	Canada
Libya	Belgium	Uzbekistan	Belgium
Algeria	Poland	Oman	Belarus
Azerbaijan	Australia	Germany	United Arab Emirates
Colombia	Greece	Bolivia	Mexico
Oman	Sweden	United Kingdom	Brazil
United Kingdom	Indonesia	Myanmar	India

With these data from the network analysis, no meaningful implications nor conclusions were possible due to the large number connections. To resolve this, we excluded statistically insignificant connections and reconfigured the network using only the major connections.

Network Reconfiguration

The methodology of reconfiguring a network by simplification has been widely used in the natural sciences, where complex networks are often addressed. Serrano et. al.'s methodology considers the number of connections between two actors as the weight of the connection and interprets each normalized weight as a random variable [16]. Connections with weights that deviate from the uniform distribution are excluded. In this case, the excluded connections vary by significance level. As the significance level decreases, the number of excluded connections increases.

We compared the reconfigured networks by altering the significance level to 1%, 5% and 10%. However, it was difficult to derive meaningful conclusions and implications since too few connections remained after the reconfiguration. Therefore, we adjusted the significance level to 20% and a network composed of the significant links at this level was derived and analyzed. Figure 1 presents the reconfigured network, which is composed of 84 links with a total weight of 1,858 (reduced from the original weight of 14,932) by reconfiguration. A link repeated more than twice is displayed as bold, meaning that the two countries tied by a bold link are more firmly connected through common membership in more international energy organizations. For visual convenience, the bolder links show the strongest connections.

In the reconfigured network, the average number of links each for country is 6.4, meaning each country connects with 6.4 countries on average. In terms of the centralization index, the value increased from 0.06 to 0.32, which means that the network became more centralized after being reconfigured. The density index decreased sharply from the previous value of 0.94 to 0.13 as only significant links remained.

The reconfigured network includes 12 countries in the center, including France, Germany, the United Kingdom, Indonesia, Brazil, the United States, Canada, Australia, Japan, Korea, China, and India, while the other 37 countries are in the periphery. Among them, Angola, Kuwait, Bolivia, Egypt, Trinidad and Tobago, Belarus, Ukraine, Uzbekistan, Myanmar, and Turkmenistan have no significant connection with other countries. The overall composition of the network shows that countries form two major groups. Saudi Arabia, Libya, Algeria, the United Arab Emirates, Venezuela, Iraq, Iran, Qatar, and Nigeria form a group of exporters, while the other countries form a larger group of both exporters and importers. In addition, the two groups are linked by Oman and Kazakhstan, which are connected to each group through Russia, Nigeria, and Azerbaijan.

Comparison Analysis

This study compares network characteristics of three groups of trade type. While the initial sample is composed of two groups (i.e., exporting and importing countries), ten countries are included in both groups. These countries were classified as balanced countries, namely Australia, Canada, Germany, Indonesia, Mexico, the Netherlands, Russia, the United Arab Emirates, the United Kingdom, and the U.S. The importing country group of 17 countries includes Belarus, Belgium, Bra-

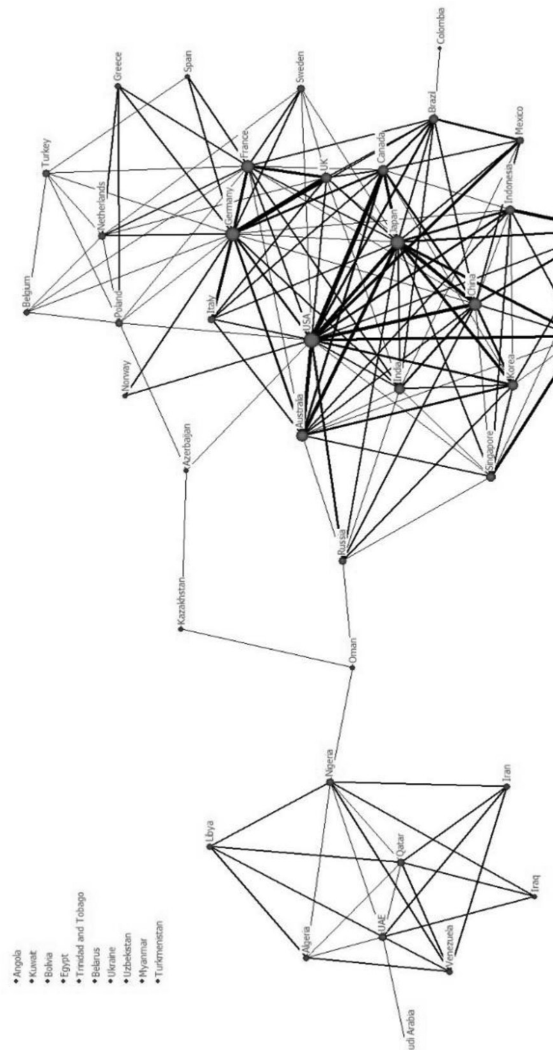

Figure 1. Major energy trading countries' network formed through international energy after simplification.

zil, China, France, Greece, India, Italy, Japan, Poland, Korea, Singapore, Spain, Sweden, Thailand, Turkey and Ukraine. The exporting country group consists of 22 countries including Angola, Algeria, Azerbaijan, Bolivia, Colombia, Egypt, Iran, Iraq, Kazakhstan, Kuwait, Libya, Malaysia, Myanmar, Nigeria, Norway, Oman, Qatar, Saudi Arabia, Trinidad and Tobago, Turkmenistan, Uzbekistan and Venezuela.

To compare these three groups, we focus on two widely used characteristics in social network analysis. First, the degree index is derived by normalizing the number of other countries with which a focal country connects. The higher index is associated with the greater number of countries with which the focal country directly cooperates. This enables the country to closely cooperate with more countries. The next characteristic is about the influence of a focal country within the network and Bonacich's power centrality [17] was measured as the influence, shown in Equation 2:

$$c(\alpha,\beta) = \alpha\sum^{\infty}_{k=0} \beta^k R^{k+1} 1, \tag{2}$$

In this equation, α is a scaling factor, β is a weighting factor, R is a matrix of relationships, and 1 is a column vector of 1's. In the matrix, all main diagonal elements are set to 0. And each element rij and rji in the matrix R takes the value of 1 if a tie occurs or 0 otherwise. Additionally, the designation of β follows the example of previous research, which sets it equal to three-quarters of the reciprocal of the largest eigenvalue [18]. According to this measure, a country's power is a positive function of the number of its links and the power of other countries with which the focal country forms links.

Table 3 shows degree and power centrality indices of countries belonging to the three groups. As the sample numbers of the three groups are 18, 22, and 9, which appear not to follow a normal distribution, a non-parametric test is used for comparing the two indices. Moreover, instead of a simultaneous comparison among the three groups, each pair was compared by using Wilcoxon's rank sum test three times [19,20].

Analysis Results

The comparison analysis found that the exporting country group showed a significant difference from the other two groups. Between the importing and exporting groups, the former had significantly higher values in terms of both degree and power centrality ($p < 0.001$). With

Table 3.
Network characteristics of countries: degree and power centrality.

Import Country	*Degree*	*Power Centrality*	*Export Country*	*Degree*	*Power Centrality*
Belarus	0	0	Algeria	0.104	0.005
Belgium	0.104	0.282	Angola	0	0
Brazil	0.208	1.210	Azerbaijan	0.063	0.185
China	0.333	2.070	Bolivia	0	0
France	0.354	1.536	Colombia	0.021	0.072
Greece	0.083	0.303	Egypt	0	0
India	0.250	1.380	Iran	0.083	0.004
Italy	0.146	1.095	Iraq	0.063	0.003
Japan	0.375	2.425	Kazakhstan	0.042	0.015
Poland	0.167	0.472	Kuwait	0	0
Korea	0.229	1.493	Libya	0.083	0.004
Singapore	0.208	1.203	Malaysia	0.167	1.260
Spain	0.063	0.259	Myanmar	0	0
Sweden	0.125	0.652	Nigeria	0.167	0.010
Thailand	0.146	1.079	Norway	0.042	0.335
Turkey	0.125	0.304	Oman	0.063	0.061
Ukraine	0	0	Qatar	0.146	0.006
			Saudi Arabia	0.021	0.001
Balanced Country	*Degree*	*Power Centrality*	Trinidad and Tobago	0	0
Australia	0.292	2.018	Turkmenistan	0	0
Canada	0.250	1.858	Uzbekistan	0	0
Germany	0.396	1.864	Venezuela	0.104	0.005
Indonesia	0.208	1.383			
Mexico	0.125	0.969			
Netherlands	0.167	0.461			
Russia	0.167	0.982			
UAE	0.167	0.007			
UK	0.250	1.552			
USA	0.438	2.628			

regard to the comparison between the balanced and exporting country groups, the exporting country group had significantly lower degree and power centrality ($p < 0.001$) as the first comparison. Categorized as a balanced country, the U.S. had both the highest degree (0.438) and power centrality (2.628) of all countries considered. Comparisons between the importing and balanced country groups did not show any significant difference in either indices. Table 4 presents the analysis results. Both the importing and balanced countries occupy more central positions with more partners in the network than the exporting countries.

Table 4a.
Wilcoxon's rank sum test: degree comparison between import and export groups.

Degree	*Observation*	*Actual rank sum*	*Expected rank sum*
Import country group	17	460.5	340
Export country group	22	319.5	440
Combined group	39	780	780
Unadjusted variance	1,246.67		
Adjusted variance	1,222.06		
z	3.447		
Prob > |z|	0.0006		

Table 4b.
Wilcoxon's rank sum test: power centrality comparison between balanced and export groups.

Degree	*Observation*	*Actual rank sum*	*Expected rank sum*
Balanced country group	10	269	165
Export country group	22	259	363
Combined group	32	528	528
Unadjusted variance	605		
Adjusted variance	592.47		
z	4.273		
Prob > |z|	0.0000		

Table 4c.
Wilcoxon's rank sum test: degree comparison between import and balanced groups.

Degree	*Observation*	*Actual rank sum*	*Expected rank sum*
Balanced country group	10	175.5	140
Import country group	17	202.5	238
Combined group	27	378	378
Unadjusted variance	396.67		
Adjusted variance	393.76		
z	1.789		
Prob > |z|	0.0736		

Table 4d.
Wilcoxon's rank sum test: power centrality comparison between import and export groups.

Degree	*Observation*	*Actual rank sum*	*Expected rank sum*
Import country group	17	477	340
Export country group	22	303	440
Combined group	39	780	780
Unadjusted variance	1246.67		
Adjusted variance	1225.59		
z	3.913		
Prob > |z|	0.0001		

Table 4e.
Wilcoxon's rank sum test: power centrality comparison between balanced and export groups.

Degree	*Observation*	*Actual rank sum*	*Expected rank sum*
Balanced country group	10	265	165
Export country group	22	263	363
Combined group	32	528	528
Unadjusted variance	605		
Adjusted variance	595.46		
z	4.098		
Prob > |z|	0.0000		

Table 4f.
Wilcoxon's rank sum test: power centrality comparison between import and balanced groups.

Degree	*Observation*	*Actual rank sum*	*Expected rank sum*
Balanced country group	10	169	140
Import country group	17	209	238
Combined group	27	378	378
Unadjusted variance	396.67		
Adjusted variance	396.55		
z	1.456		
Prob > |z|	0.1453		

CONCLUSIONS

This study classified 49 major oil and natural gas trading countries into exporting, importing, and balanced country groups. It compared two network characteristics of each group within a network formed through participation in 28 international energy organizations. Both importing and balanced countries showed higher values for degree and power centrality indices than the exporting countries. However, there was no significant difference between the importing and balanced countries. The results indicate that countries having considerable imports occupy more central positions with more partners, which increases their influences within the network. In other words, countries that are active in oil and natural gas imports, regardless of their exports, are more active participants in international energy organizations than countries focusing only on exports. Therefore, oil and natural gas imports seem to be a more critical factor in determining international energy organization participation than exports. This conclusion is reinforced by the case of rich countries, such as Kuwait, Norway, and Qatar, included in the exporting country group. This implies that the differences are not simply due to national wealth.

One of the reasons that led to this difference might be the efforts of importing countries to strengthen their energy security. In particular, importing countries suffered from the oil shocks in 1970s and their experiences reinforced the importance of energy security. Their efforts to reduce this risk through collective actions included creating organizations such as the International Energy Agency [21]. Their collective efforts extended to more active international energy cooperation and memberships in international energy organizations. The higher participation of importing countries continued until recently, as the oil and gas markets have become more supplier-oriented. With shale oil development and weaker growth in energy demand, the difference in participation between exporting countries and others is expected to disappear.

As responses to climate change increase worldwide, the bargaining power of fossil fuel-exporting countries will decline. The more their markets become consumer-oriented, the more effort exporting countries will make not to lose their current market shares. Exporting countries who in the past focused on bilateral oil and natural gas trading are likely to join multilateral cooperation mechanisms, such as international energy organizations. Oil and natural gas exporting countries tend to participate in international energy organizations due to the reduction of their bargaining power and their greater involvement in climate change responses. Through various international energy organizations, oil and gas exporting countries are attempting to either affect the international energy cooperation agenda for their own interests or utilize policy references from other countries.

Countries that have been passive in international energy cooperation are realizing the need to increase their participation in international energy organizations. With greater concerns regarding climate change, interest in renewable energy and energy efficiency is increasing. International organizations such as the International Renewable Energy Agency and the International Partnership for Energy Efficiency Cooperation are expanding their operations. With increasing energy market uncertainty and risks, international cooperation among governments will increase along with private cooperation. All these changes will be reflected in the international energy cooperation network of countries, and the network investigated in this study is expected to have denser linkages in the future.

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