

РАЗНООБРАЗИЕ ИМПОРТА ЭНЕРГОРЕСУРСОВ СТРАН-ИМПОРТЕРОВ ЭНЕРГИИ: ФОКУС НА КОРЕЮ И ЯПОНИЮ

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Аннотация. В данной статье делается попытка оценить разнообразие импорта энергоносителей Республики Корея и Японии, которые являются двумя крупнейшими странами-импортерами энергии и имеют более высокий уровень зависимости от импорта энергоносителей. Разнообразие в импорте энергии является одной из основных концепций, составляющих концепцию энергетической безопасности, которая считается основой национальной энергетической политики в этих странах. Для оценки разнообразия импорта энергии используется индекс разнообразия Шеннона, который является одним из широко используемых индексов разнообразия в области энергетического разнообразия, и измеряется индекс с 2000 по 2015 год. Индексы разнообразия импорта основных ресурсов ископаемого топлива, нефти, природного газа и угля показывают разные уровни и тенденции в обеих странах. Композитный индекс разнообразия импорта энергоресурсов стран улучшился с 2009 года, чему способствовал индекс разнообразия импорта природного газа. Российский природный газ способствовал увеличению индекса разнообразия природного газа, и ожидается, что индекс разнообразия может быть увеличен в будущем за счет увеличения объема импортируемого российского природного газа. Между тем обеим странам по-прежнему необходимо улучшить разнообразие импорта нефти, несмотря на уменьшение доли нефти в их TPES, учитывая важность нефти в отраслях промышленности стран и очень высокую зависимость импорта нефти от Ближнего Востока.

Ключевые слова: разнообразие импорта энергоносителей, энергетическая безопасность, импорт ископаемого топлива Кореи и Японии, зависимость импорта энергоносителей Кореи и Японии, российские энергоресурсы.

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ENERGY IMPORT DIVERSITY OF ENERGY IMPORTING COUNTRIES: FOCUS ON KOREA AND JAPAN

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Abstract. This article tries to assess the energy import diversity of the Republic of Korea and Japan, which are 2 of the biggest energy importing countries and have a higher level of dependency on energy import. Diversity in energy import is one of the major concepts composing the concept of energy security, which is considered as the basement of national energy policy in those countries. In order to assess the energy import diversity, we employ Shannon's diversity index that is one of the widely used diversity indexes in the field of energy diversity and measure the index from 2000 to 2015. The import diversity indexes of major fossil fuel resources, which are oil, natural gas, and coal, show different levels and trends in both countries. The composite diversity index of energy import of the countries has improved from 2009 and it has been stimulated by the import diversity index of natural gas. Russian natural gas has contributed to the increase in the diversity index of natural gas and it is expected that the diversity index of natural gas could be increased more in the future by the increased volume of imported Russian natural gas. Meanwhile, it is still necessary for both countries to improve oil import diversity, despite the decreasing share of oil in their TPES considering the importance of oil in the industries of the countries and very high dependency of oil imports on the Middle East.

Keywords: energy import diversity, energy security, fossil fuel import of Korea and Japan, energy import dependency of Korea and Japan, Russian energy resources.

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Introduction

Stable supply and efficient use of energy resources is one of the most basic and important elements for sustainable growth of a national economy, social development, and improvement of people's standard of living. In the national economy as a cycle of production and consumption, energy resources play the role of guaranteeing the quality of life and the basic element of production. This is the reason why, since the first industrialization, stable supply of fossil fuel resources such as coal, oil, and natural gas has been recognized as one of the top priorities for developing countries as well as developed countries (except for some oil-producing countries). For Korea and Japan, a stable supply of energy resources is one of the top priorities in national security issues. These two countries, which have no fossil energy resources in their territory, heavily rely on imports of primary energy resources. In particular, fossil fuels such as petroleum and natural gas supply in these countries nearly 100% depend on imports, most of which depend on the Middle East. In addition, the industrial structure that has high-energy consumption, high level of electrification and energy infrastructure make the stable energy supply and management more important. In this context, the concept of energy security is considered as the basement of national energy policy in those countries. Energy security has been defined variously by researchers. There is a broad consensus on what energy security should deal with, but there is no consensus on exactly what energy security should be [1]. Energy security sometimes refers to the availability of energy resources by geopolitical factors, the extent of infrastructure for stable energy supply, or the availability of energy resources in relation to energy prices. The concept of energy security has been used in these various contexts and definitions. In a broad sense, however, energy security generally refers to the stability of energy supply in the case of energy importing countries, and to the stability of energy production and exports in the case of energy exporting countries. The IEA defines energy security as "the uninterrupted physical availability at a price which is affordable, while respecting environmental concerns" [2] and defines energy security as the security of supply of energy resources. In particular, traditional discussions on energy security focus on primarily the stability and sustainability of oil supplies [3]. In the concept of stability of energy supply, the diversity is one of the main pillars. This stability can be divided into structural stability and the economic efficiency of energy supply. The structural stability of the energy system can be expressed in terms of diversity. High dependency on a specific energy supplier or energy source, i.e. low diversity, has an increased impact of

the individual supplier or energy source on the energy system and increases risk. As energy demand is perceived as a component of energy security [4], it is argued that reducing energy consumption and dependency will increase energy security [5]. In this article, we very focus on import diversity.

Literature review

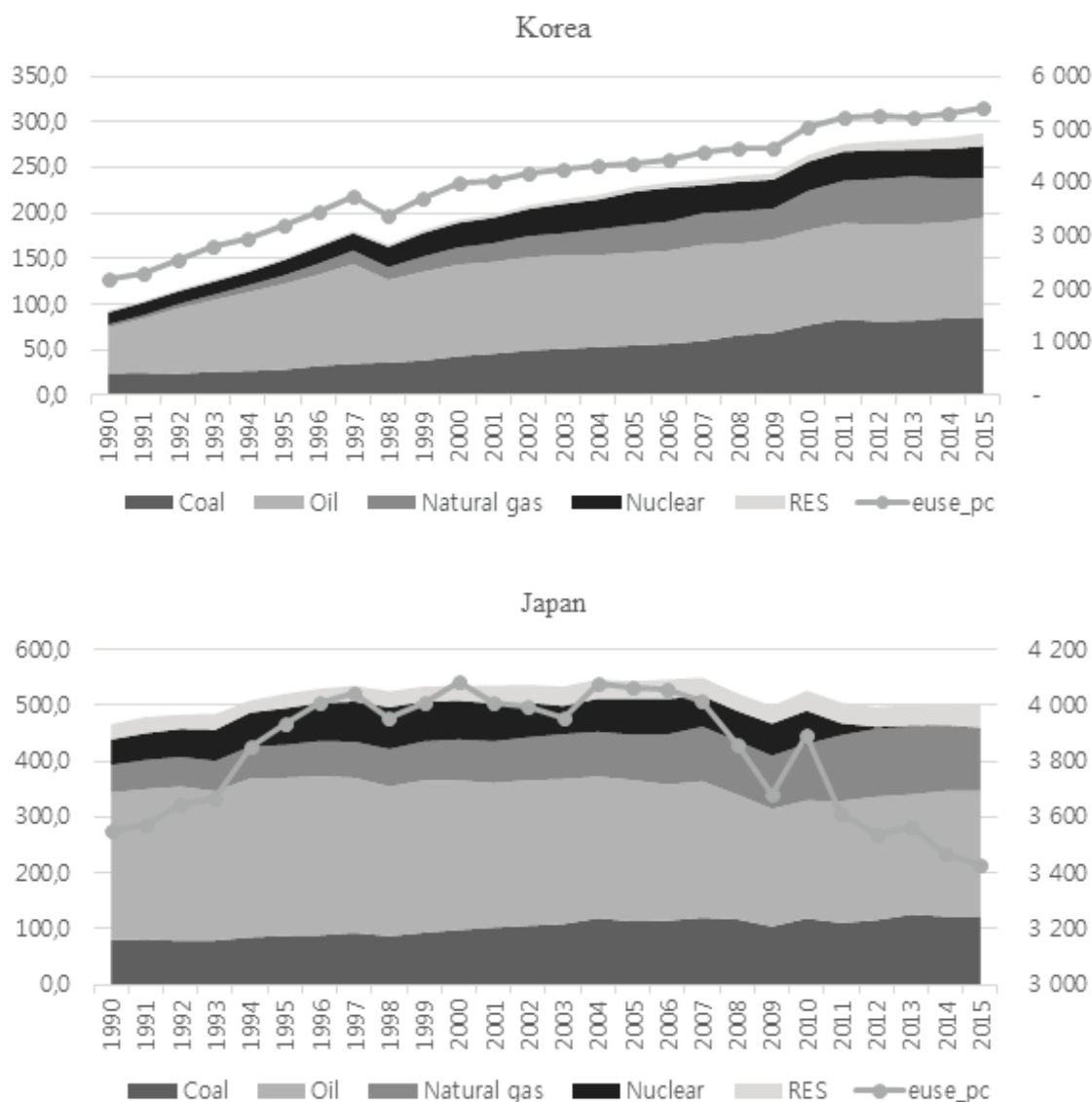
Many studies on energy security have dealt with a diversity of energy supply. Jang, Yong-Chul et. al. [6] employ Shannon's diversity index in order to assess the energy security of Korea. They analyze widely used concepts and indexes for assessing energy security. The authors argue that the diversification of energy sources brings a reduction of dependency on specific energy sources and as a result, risk in energy security is decreased. Based on the concept, the article assesses the diversity of primary energy sources of Korea and compares Korea with G7 countries. B. Krut'et. al. [7] provides an overview of available indicators for long-term security of supply. The author distinguishes four dimensions of energy security that relate to the availability, accessibility, affordability, and acceptability of energy and classifies indicators for energy security according to this taxonomy. E. Kisel el. al.[8] presents an Energy Security Matrix that structures relevant energy security indicators from the aspects of Technical Resilience and Vulnerability, Economic Dependence and Political Affectability for electricity, heat, and transport fuel sectors. The article employs Herfindahl Index in order to assess diversity of electricity and heat supply (similar to diversity of energy source in TPES) and transport supplies. V. Vivoda [9] explores approaches to LNG import diversification of China, Japan, Korea, India, and Taiwan, which are the 5 largest importers in the region between 2002 and 2012 and explains why patterns of LNG imports differ between states and over time. The article assesses diversity of LNG import of the countries using Herfindahl Index from 2002 to 2012. With a similar approach, E. Gupta [10] assesses import diversity of the 26 net oil-importing countries using Herfindahl Index in its assessment on the relative oil vulnerability of the countries. Andreas Loschelet. al. [11] shed light on diverse indicators of diversity employed in studies on energy security and develop their own indicator for assessing energy security of industrialized countries. These articles have very similar approach to our article, but they just focus on the import of single energy-source and considers only exporting countries in the diversity index. Our article tries to one more step toward adding all 3 major fossil fuel energy sources, oil, natural gas, and coal in the diversity index and considering regional diversity factor.

Energy supply-demand environment of Korea and Japan

The energy consumption of Korea has steadily increased since 1990 except for 1998 when the financial crisis has occurred. Total primary energy supply

(TPES) was 93.2 mtoe (Million ton of oil equivalent) in 1990 and it became double just for 10 years. In 2015, it recorded 287.5 mtoe, which is 3 times bigger than TPES in 1990. The dominant energy source has been oil and coal had 2nd place in TPES.

Figure 1. TPES (mtoe) and Energy use per capita (kg of oil equivalent) of Korea and Japan



Source: Statistical bureau of Korea¹, Statistical Bureau of Japan², World Bank³

Unlike the share of oil has decreased for the last 25 years, the share of natural gas has grown in the fast tempo from 3.2% in 1990 to 15.2% in 2015. The energy consumption per capita also has grown steadily and shows a higher level comparing to the OECD aver-

age. In 1990 the energy consumption per capita was 2,167 kg of oil equivalent and has grown by 5,413 kg in 2015. It is higher than that of Japan and OECD average, which was 4,154 kg of oil equivalent in 2015. In summary, both the total energy consumption and energy

¹ Statistical bureau of Korea. Korean Statistical Information Service. Available at: <http://kostat.go.kr/portal/korea/index.action> (accessed 10.09.2019) (in Korean / English).

² Statistical bureau of Japan. Japan Statistical Yearbook 2019. Available at: <https://www.stat.go.jp/english/> (accessed 10.09.2019) (in Japanese/English).

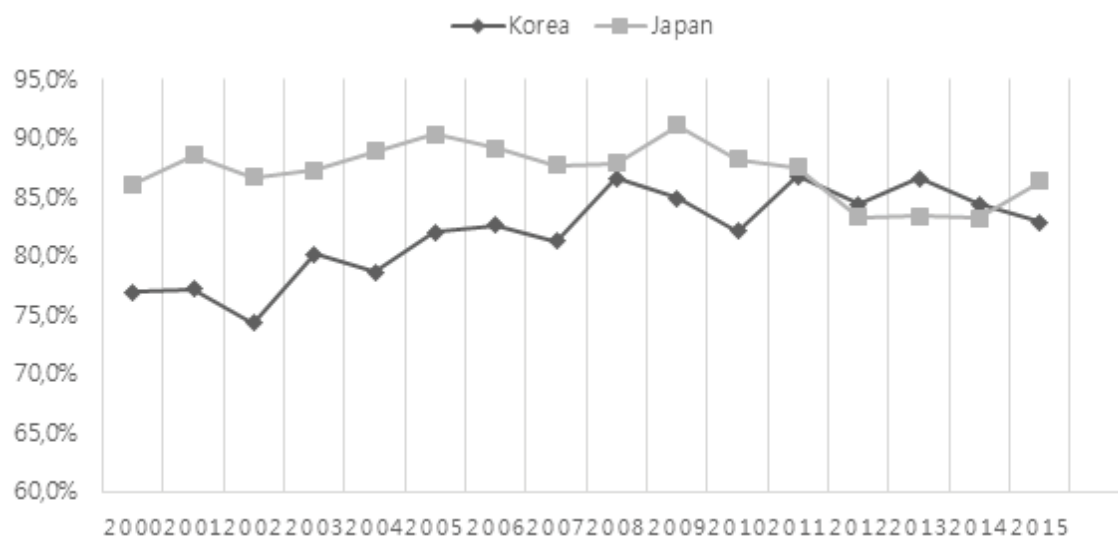
³ World Bank. World Bank Open Data. Available at: <https://data.worldbank.org/> (accessed 10.09.2019) (in English).

consumption per capita in Korea have grown and had growing demand for natural gas. Unlike Korea, Japan has stagnant total energy consumption but it is almost double in the volume of TPES. Its TPES was 466 mtoe in 1990 and has grown in slow tempo by 2004. After then it began to decrease and marked 500 mtoe in 2015. Japan has similar TPES structure to Korea, in which the share of oil has been biggest from 56.6% in 1990 to 44.7% in 2015 as well as coal and natural gas has followed. The energy consumption per capita also has similar tendency. In 1990 it was 3,551 kg of oil equivalent, which was higher than that of Korea, but after 2000 it began to decrease and it has been shrunk by 3,429 kg in 2015.

The oil supply into S. Korea's economy absolutely depends on imports. According to IEA and UN Comtrade, S. Korea imported 179 million tons of oil (crude oil and oil products) from 46 countries in the world in 2015. Its volume of oil imports shows an increasing tendency in general. The absolute volume of oil import has been smaller than that of Japan, but as its

import increase and Japan's import decrease, the gap between Korea and Japan has been becoming smaller. The biggest exporter for Korea is Saudi Arabia, which has 30.2% of the total share. The top 5 exporters, Saudi Arabia, Kuwait, Iraq, Qatar, and UAE, take 78.3% of the total share in oil import of S. Korea. After these big 5 exporters, Russia has the 6th position with 6.02% of the total share. As seen in the top 5 exporters list, S. Korea very depends on Middle East countries in oil import. In 2015 the share of Middle East countries in the total oil import was 83% and it's never been below 77% since 2000. This high dependency on Middle Eastern crude oil and on some specific countries has been considered as a potential threat to the energy security of S. Korea and the Korean government has sought to the diversification of crude oil supply routes since two times of Oil Shock. This effort for the diversification seemed effective by 1999, however, since 2000, with the high price of crude oil in the global market, the dependency has started to rise up again and hit the peak in 2011 (87.1%) as we see in [Figure 2] below.

Figure 2. Oil import dependency on the Middle East, %



Source: UN Comtrade⁴

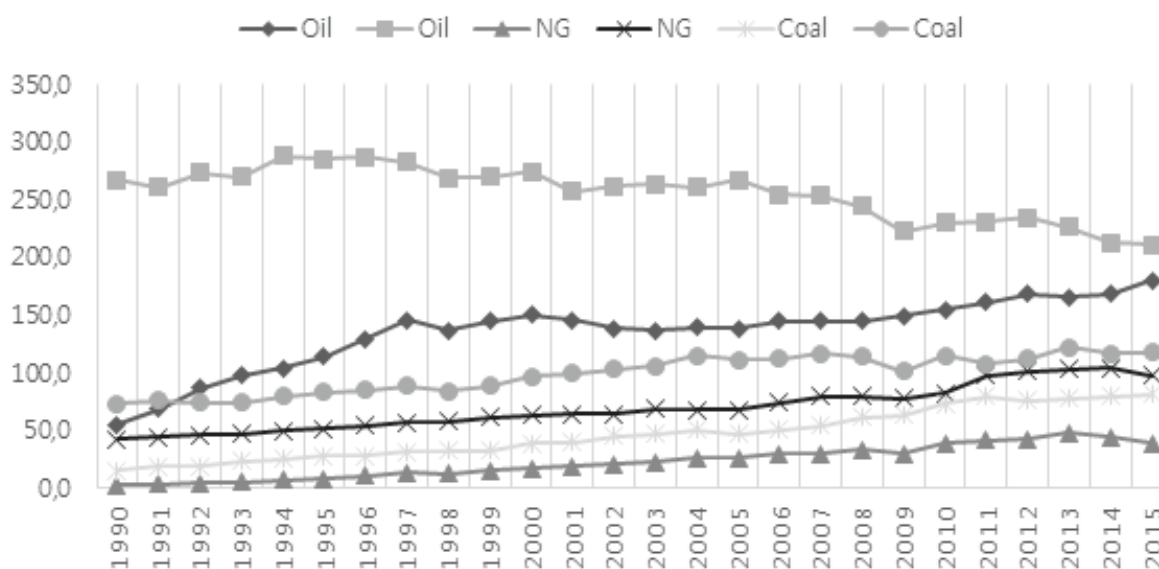
This tendency is because of some reasons; reduced exporting capacity of Southeastern countries due to their increasing domestic demands; the high transporting cost of American crude oil; increasing market share of Middle Eastern crude oil in the global market; nominal policy for diversification of oil-importing routes of Korean government [12]. Japanese oil import has decreased since 1990. It was 267 million ton, which was more than 4 times bigger than that of Korea, but steadily shrunk by 211 mton in 2015. Japan has a similar situation to S. Korea in oil import. It also

has no oil reserve in its territory and most of its domestic oil demands are compensated by imported oil. The top 5 oil-exporters for Japan, Saudi Arabia, UAE, Qatar, Kuwait, and Iran, take 82.6% of the total oil import of Japan. Saudi Arabia turns out unchallenged no.1 exporter for Japan. It exports 59.1 mton of oil in 2016 and it takes 35% of the total oil import of Japan. The share of Saudi Arabia in Japanese oil imports has grown since 2000 from 23% to 35% in 2016. Like in Korea Russia takes 6th place with 6.1% of the share. As [figure 2] shows Japan also has a high dependency on

⁴ UN Comtrade. UN Comtrade Database. Available at: <https://comtrade.un.org/> (accessed 19.09.2019) (in English)

the Middle East in oil import and it's never been lower than 80% since 2000⁵. Russia's share has grown from 0% in 2000 to 6.1% (9.9 mton) in 2016.

Figure 3. Imported volume of oil, natural gas, and coal to Korea and Japan, mtoe



Source: IEA⁶

S. Korea and Japan are the major importers in the global natural gas market. According to IEA and UN Comtrade, Japan imports 97.8 mtoe of natural gas and S. Korea imports 38.9 mtoe in 2015. In 2015, S. Korea imported approximately 20 mtoe of natural gas from the Middle East in forms of LNG, which takes 51% of total gas imports. The major sources of gas imports for the country are Qatar, Oman, Indonesia, Malaysia, and Russia. S. Korea bought 13.1 mtoe from Qatar, 3.9 mton from Oman and 3.7 mtoe Indonesia, 3.7 mtoe from Malaysia, and 2.6 mtoe from Russia. S. Korea has started to import Russian gas from 2009 with 1.01 mtoe, 3% of total and it maintains its share on the level of 5% to 7%. Unlike S. Korea, Japan has a higher share of the Asia-Pacific region in natural gas imports. Australia, exported 19.3 mtoe (20.7% of total) of LNG to Japan in 2015, is the biggest supplier for Japan. Qatar has second place with 17.1 mtoe (18.3%) and Malaysia (15.5 mtoe, 16.6%), UAE (7.8 mtoe, 8.3%), and Russia (7.5 mtoe, 8.0%) follow in order. Japan also has started to import Russian LNG from 2009, 2.7 mtoe and it maintains about 7-8 mtoe level. At the regional level, these countries have a similar degree of dependency in gas imports, but they depend on different regions. S. Korea depends on Middle East (51%) and Japan buys 52% of imported gas from the Asia-Pacific region. However, at the level of exporting countries, Japan shows much higher diversity than that of S. Korea. Japan imports

natural gas from 28 countries and the top supplier, Australia, takes just 20% in the total. It is relatively lower. S. Korea's top supplier, Qatar, takes 33% in the total. In addition to this, gaps between the top supplier and second supplier are smaller in the Japanese gas import than in Korea. The gap between Australia, the top supplier for Japan, and Qatar, second supplier, is 2.2 mtoe, but this gap in S. Korea is 9.1 mtoe. Japanese portfolio in natural gas imports could be more diversified after 2017 when it begins to import American shale gas, which takes approximately 20% of annual natural gas imports of Japan.

In coal import, both countries very depend on Australia. In 2015 Korea imported 81 mtoe of coal in total. Among them about 45% came from Australia, 25% from Indonesia, 17% from Russia, 7% from Canada, 3% from USA, and 2% from China. Japan imported 117 mtoe of coal in 2015 and among them, about 65% came from Australia, 17% from Indonesia, 9% from Russia, 4% from Canada, 3% from the USA, and 1% from China.

Assessing energy import diversity of Korea and Japan

Shannon-Wiener's diversity index [13], which is used to measure species diversity in an ecosystem in ecology, represents the diversity of the entire ecosystem, taking into account both the share of species and their relative proportions.

⁵ Data in 2015 shows strange number. Considering time serial tendency, looks it is statistical error.

⁶ IEA, Statistics data browser. Available at: <https://www.iea.org/statistics/> (accessed 19.09.2019) (in English)

$$\text{Shannon Index}(H) = - \sum_{i=1}^s p_i \ln p_i \quad [\text{Eq. 1}]$$

Where, p_i is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), \ln is the natural log, Σ is the sum of the calculations, and s is the number of species.

Here we can measure energy import diversity by replacing the ecosystem with the energy import structure of the country i , and replacing individual species with energy-exporting countries. Shannon-Wiener's Diversity Index is modified to show the energy import diversity D_{import} as follows.

$$D_{import} = \omega_{oil} \cdot D_{oil} + \omega_{gas} \cdot D_{gas} + \omega_{coal} \cdot D_{coal} \quad [\text{Eq. 2}]$$

Where,

D_j : import diversity of energy resource $j = (-\sum_i^N s_i \log_2 s_i) \cdot (-\sum_k^N r_k \log_2 r_k)$

$-\sum_i^N s_i \log_2 s_i$: import diversity of energy resource j at country level

s_i : share of exporting country i in total import of energy resource j

$-\sum_k^N r_k \log_2 r_k$: import diversity of energy re-

source j at the regional level

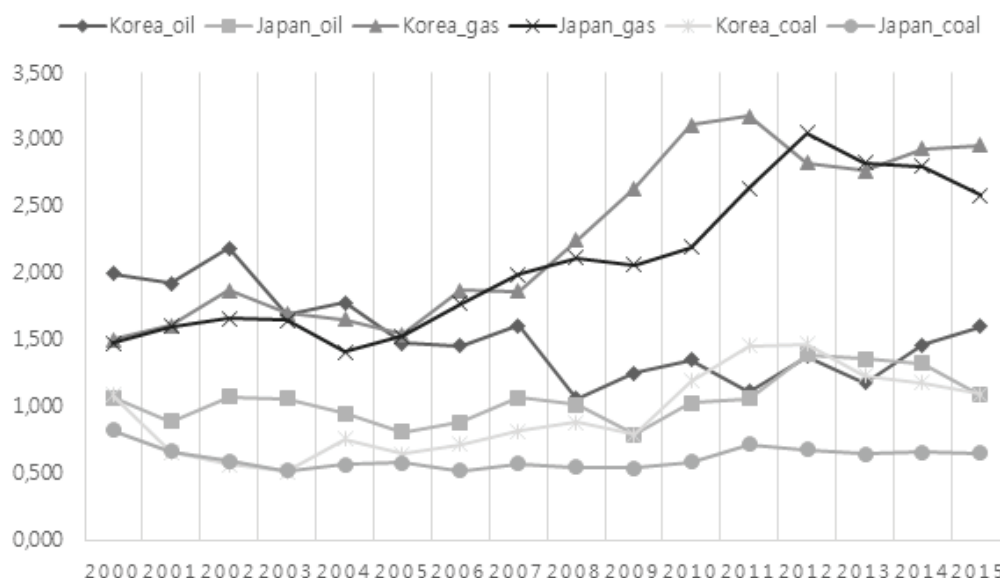
r_i : share of exporting region i in total import of energy resource j

ω_i : Share of energy resource i in TPES

The energy import diversity represents the diversity of oil, natural gas, and coal imports, which are major fossil fuel. In the previous section, we examined the crude oil and gas import volume and share by exporters in 2015 in Korea and Japan. Here we will use the Shannon-Wiener Diversity Index, referred to in [Eq. 1], as a comprehensive and objective indicator of the diversity of oil, natural gas and coal import. The data used here was provided by UN Comtrade from 2000 to 2015⁷. Crude oil was searched by HS code 2709, natural gas was HS code 2711, and coal was HS code 2701, all in kg units.

First, the diversity index of crude oil imports in Korea and Japan is shown in [Figure 3]. The crude oil import diversity index of Korea and Japan is similar and low. Both countries have depended on the Middle East for more than 80% of their oil imports, so such low crude oil import diversity index is a reasonable result. The medium-term trend shows slightly different features. In Korea, the diversity of oil imports steadily declined from 2000 to 2013, dropped to about 60% of the 2000 level. On the other hand, in Japan, the diversity index has not changed much since 2000.

Figure 4. Crude oil, natural gas, and coal import diversity index of Korea and Japan



Source: Author, based on UN Comtrade data

In the natural gas import diversity index, Korea and Japan show a significantly higher value than their crude

oil diversity index. In both countries, the diversity index has been improving since the mid-2000s. In the early 2000s, the natural gas import diversity index of both

⁷ It appears that there are some omissions in the Middle East imports in Japan's 2015 crude oil import details data provided by Comtrade. To compensate for this, data for 2015 will replace data for 2016.

countries has been around 1.5. They started to increase steadily until 2005 and jumped to the 3-point level in 2009 when the countries began to import Russian LNG. Since then they keep an index of the 2.5-point range. The diversity of natural gas imports in the two countries is better than that of crude oil. In the case of Korea, the dependency on the Middle East in natural gas import, which is the largest source at the regional

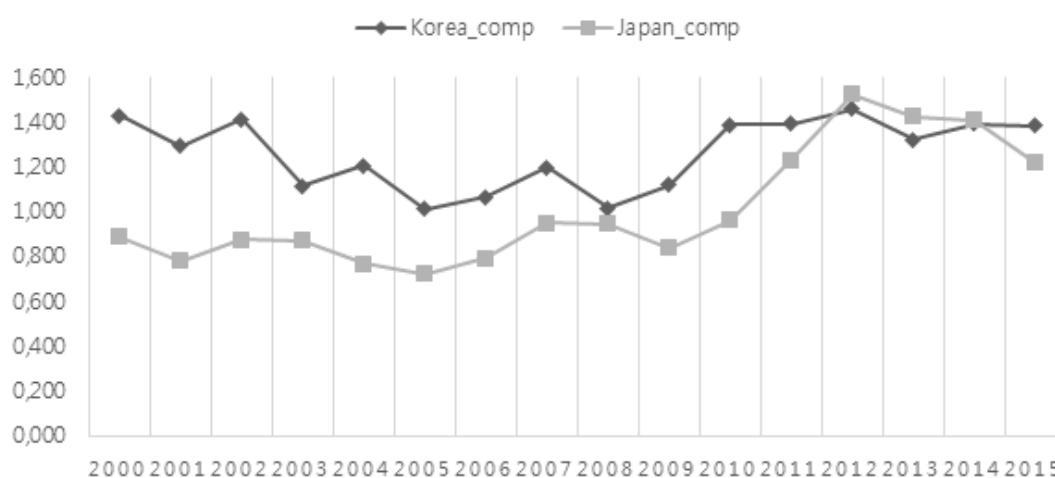
level, is about 50%, and Japan has Asia as the largest importing source at the regional level (50%). In other words, considering de-facto no differences between the number of oil-exporting countries and the number of natural gas exporting countries to them, the big difference between the crude oil diversity index and the natural gas diversity index arises from the difference in regional dependency.

Table 1. Share of oil, natural gas and coal in TPES by country, %

	Korea			Japan		
	Oil	NG	Coal	Oil	NG	Coal
2000	52.0	9.8	22.2	49.9	13.7	18.4
2001	50.6	10.5	23.0	48.2	14.0	19.1
2002	49.1	11.1	23.5	48.5	14.3	19.7
2003	47.6	11.2	23.8	48.5	15.1	20.4
2004	45.7	12.9	24.1	46.3	14.7	21.8
2005	44.4	13.3	24.0	46.5	14.9	20.9
2006	43.6	13.7	24.3	44.5	16.4	21.1
2007	44.6	14.7	25.2	44.4	17.8	21.9
2008	41.6	14.8	27.4	42.7	18.4	22.5
2009	42.1	13.9	28.2	42.1	19.1	21.0
2010	39.5	16.3	29.2	40.1	19.2	22.6
2011	38.0	16.7	30.2	43.1	23.3	22.0
2012	38.1	18.0	29.1	44.3	24.5	23.4
2013	37.8	18.7	29.2	42.7	24.2	25.1
2014	37.1	16.9	29.9	44.6	23.6	24.4
2015	38.1	15.2	29.7	44.7	22.3	24.6

Source: Statistical bureau of Korea, Statistical Bureau of Japan

Figure 5. Composite energy import diversity index of Korea, Japan, and China



Source: Author

Korea and Japan's coal import-diversity indices are relatively low compared to those of crude oil and natural gas. Korea's coal import diversity index, which was about 1.086 in 2000, decreased to 0.6 in 2005, and then recovered to 1.094 in 2015. This low diversity index appears to be due to its high import dependency on Asia and the relatively small number of exporters compared to crude oil and natural gas. Korea's coal import dependency on the Asian region has been close to 70% to 90%. The coal import-diversity index of Japan is lower than that of Korea. In addition, it has maintained a low diversity index under the 1 point. This is due to high import dependency on Asia, as in Korea. Japan's dependency on Asia is between 83% and 90%. However, the problem of diversification of coal imports in Korea and Japan seems not to be a serious problem, considering the following features of coal. That are the relatively low share of coal in the energy mix of Korea and Japan; the relatively less competitive and stable characteristics of international coal market compared to crude oil and natural gas; and the limited use of coal, which is mostly used only for power generation purposes in Korea and Japan.

Now, let's calculate the composite energy import diversity index which integrates the diversity index of crude oil, natural gas, and coal. In [Eq. 1], we defined the composite energy import-diversity index as the sum of diversity indices of individual sources weight by their share in TPES. In other words, we calculated the composite index reflecting the relative importance of individual energy sources in the energy mix to the diversity index. In [Table 1] the share of TPES by the sources in Korea and Japan is summarized.

[Figure. 5] shows the composite energy import-diversity index of Korea and Japan, calculated as above. The composite energy import-diversity index of Korea fell to 1.016 in 2009 and has increased to 1.348 in 2015. Such improvement of the index stems from the improvement of the natural gas import diversity index. Since 2000, the import diversity index of oil had decreased by 2008 and after that, it has increased a little bit with unstable tendency. This is due to the growing dependency of oil imports on the Middle East. The number of oil exporters to Korea has increased from 28 countries in 2000 to 46 countries in 2015. There is no change in number of Middle Eastern countries, but the number of Asian exporters to Korea has increased sharply from 6 to 13 and the number of European exporters to Korea also has increased from 1 to 3 countries in the same period. However, despite the increased number of exporters to Korea, the share of Middle Eastern countries to total oil import of Korea has increased from 76.9% in 2000 to 82.9% in 2015. In the same period, the share of Asian exporters has reduced from 11.4% to 3.8% and the share of African exporters also has reduced from 7.5% to 2.5%. The share of exporters in America continents insignificantly has

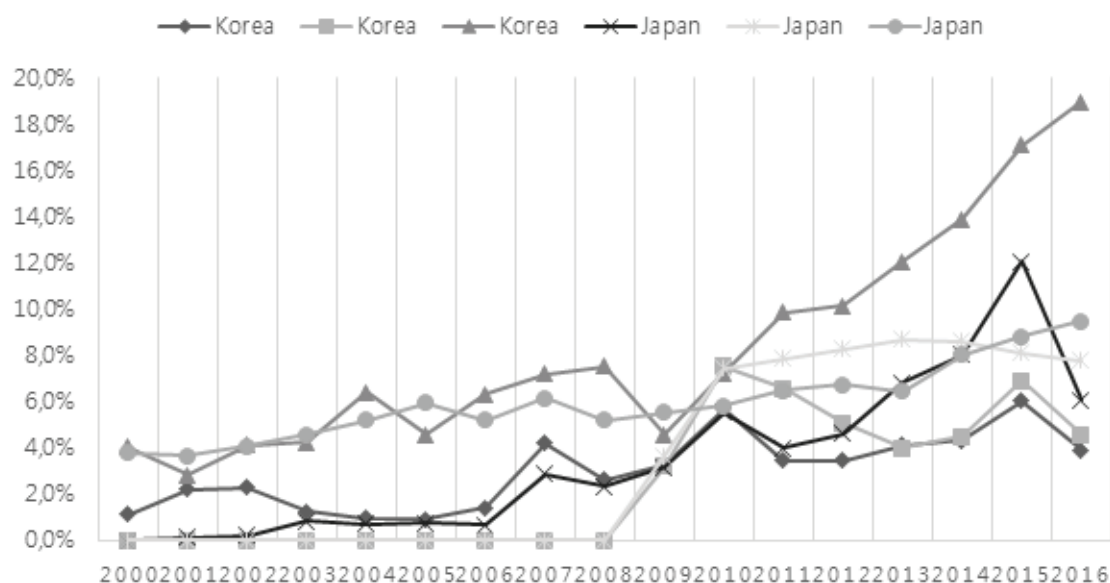
reduced from 2.5% to 2.3%, the share of European exporters and FSU exporters has increased from 0.58% and 1.12% to 2.42% and 6.12%. In other words, increase in the number of Asian exporters to Korea with decrease of the share has brought practically negative impact on the diversity index and increased share of Russian oil import has offset the negative impact of increased share of Middle East. The improvement of natural gas import diversity index has been resulted by increased number of exporters to Korea and diversification of the share of exporters. The number of exporters to Korea has increased from 20 countries in 2000 to 41 in 2015. The number of Middle Eastern exporters shows nearly no change from 6 countries in 2000 to 7 in 2015, the number of Asian exporters (from 7 to 14), African exporters (from 1 to 5), exporters in America continents (1 to 5), European exporters (5 to 9), and FSU exporters (0 to 2, mainly Russia) have increased in the period. The share by regions shows different tendencies. The share of Middle East has increased from 46.9% in 2000 to 51.4% in 2015, on the other hand, the share of Asian exporters has decreased from 51.9% in 2000 to 29.3% in 2015 despite the increased number of the exporters. The share of African exporters has increased from 0.5% to 7.2% and the share of exporters in American continents has increased from 0.6% to 4.3% in the same period. European exporters' share also has increased from 0.1% to 0.9%, but it is not significant at the absolute level. The share of FSU exporters to the total natural gas import of Korea has increased from 0% to 6.9% in 2015, it is mostly from Russia.

Japan's composite energy import diversity index also ranged between 0.7 and 0.8 by 2009 and has improved rapidly since 2009 marking 1.219 in 2015. The oil import diversity index of Japan shows a different tendency to Korea. The index has been stuck in the range of under 1.000 by 2009, but it has shown a relatively sharp increase and decreased again. Like Korea, Japan also has high level of dependency in oil import on Middle Eastern exporters. The share of Asian exporters has reduced steadily from 11% in 2000 to 3% in 2015 and this reduced share has been absorbed mostly by Russia. The share of Russia has increased from 0% in 2000 to 6% in 2015. The import diversity index of natural gas has been improved by substituting the share of Asian exporters, which was the biggest one, with the share of Russia. The share of Asian natural gas exporters to Japan has decreased a lot from 65% in 2000 to 53% in 2015, but it still has over the half. The share of Russia has increased sharply from 0% in 2000 to 4% in 2009, and to 8% in 2015.

Conclusion

By this end, import diversity of the major fossil fuel resources, which are oil, natural gas, and coal, in Korea and Japan are assessed by using diversity index and spe-

Figure 6. Share of Russian oil, gas, and coal to total import by countries



Source: UN Comtrade

cific trade data by sources. As we have seen, Korea and Japan have common features in the high level of energy consumption and very high dependency of energy supply on imports. We generate the import diversity index of oil, natural gas, and coal as well as the composite diversity index of energy import since 2000. Based on this work, we can draw following conclusions.

First, among the major fossil fuels, the diversity index of natural gas turns out relatively higher than that of oil and coal in both Korea and Japan with improving tendency. Moreover, the higher and increasing diversity index of natural gas has given a positive impact on the composite diversity index. In order words, the improvement of energy import diversity in the countries has been driven by natural gas, which has a growing share in TPES. Meanwhile, the improvement of the diversity index of natural gas has been stimulated by substituting imported volume from major exporters of Korea and Japan with Russian natural gas. In both Korea and Japan the volume of natural gas consumption will increase more, but the share in TPES will vary in these 2 countries. In 2035 the share of natural gas in TPES will increase by 19.4% according to the “2nd National Energy Master Plan” of Korea [14]. On the other hand, in Japan, the share of natural gas in TPES will decrease by 18% according to the “4th Strategic Energy Plan of Japan [15]”⁸. Therefore, the natural gas import diversity of Korea will be likely to increase more due to the increased share of natural gas in TPES, whereas at least there will not be increasing factor for the natural

gas import diversity of Japan due to the share of natural gas in TPES.

Second, there is a possibility of an additional increase in natural gas import diversity index because it is planned to expand natural gas import from Russian and the USA in both countries. Korea began to import American shale gas from 2017 [16] and made a contract to increase in the purchase of American shale gas from 2025 [17]. Japan also began to import American gas from 2017 [18] and has plan to increase the import volume [19]. Meanwhile, as we have seen, Korea and Japan began to import Russian LNG since 2009 and the import volume from Russia has increased. Although there is no specific number in the countries’ energy plan, they have set the increase natural gas import from Russia for diversification of importing routes as the top priority tasks in the national energy plan. In addition to this, Russia also plans to increase export of natural gas to those countries. According to “Energy Strategy of Russia for the period up to 2030 [20]”, Russia aims to increase the natural gas export to Asian-Pacific market by 9times comparing to that of 2015.

Third, it is still necessary for both countries to improve oil import diversity, despite the decreasing share of oil in their TPES. As an energy source, the importance of oil has been lower than in the past in both countries. Especially, the share of oil in TPES has decreased a lot in Korea since 2000. However, considering the importance of oil in the industries of the countries and very high dependency of oil imports on

⁸ Details in “Agency for Natural Resources and Energy of Japan.(2014). Long-term energy supply and demand outlook.Available at: <https://www.enecho.meti.go.jp/council/mitoshi/pdf>(Accessed 12.10.2019).

the Middle East, the diversity of oil imports still needs to be improved. As we have seen, the import-diversity index of oil increased when exporters in the other regions, such as Asian exporters and Russia, substituted the share of the Middle East. As we have seen, Russian energy resources have contributed improvement of the energy import-diversity index of the countries, although it was quite limited. Therefore, it is necessary to give policy effort that substitutes Middle Eastern oil with the other options. In this sense, Russian oil is one of the best options.

Our research provides a specific and comprehensive index system for assessing energy import diversity of energy importing countries. As we've seen in the literature review, the existing studies on the subject deal with specific sources (E. Kisel et. al.[8], V. Vivoda[9], E. Gupta[10], Andreas Loschel et. al. [11]) or focus on another side of energy supply structure, that is, diversity of energy mix (Jang, Yong-Chul et. al.[6]). Unlike the

existing studies, our article assesses diversity index of all 3 major fossil fuel sources imported to the countries, which are oil, natural gas, and coal as well as provides composite diversity index considering the sources' relative weight in the TPES. Therefore, the result of our research gives contribution to development of the research on the subject and energy security of energy importing countries. In addition to this, the result of our study has practical usefulness in the national policy-making area. In Korea and Japan, securing energy security has considered one of the top priorities in their national energy policy and the countries have sought the diversification of importing sources and routes in the major fossil fuel resources. In this context, the result of our research can provide practical index for national policy-making process. In the process of assessment and planning of diversification policy, the diversity index that shows the degree of diversity in numbers can play role as a useful tool for policy-making.

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