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Finding Loopholes in Sanctions: Effects of Sanctions on North Korea's Refined Oil Prices†

By KYOOCHUL KIM*

The international community's sanctions against North Korea, triggered by North Korea's nuclear tests and by missile development in the country, are considered the strongest sanctions in history, banning exports of North Korea's major items and limiting imports of machinery and oil products. Accordingly, North Korea's trade volume decreased to the level of collapse after the sanctions, meaning that the sanctions against North Korea were considered to be effective. However, according to this paper, which analyzed the price fluctuations of refined petroleum products in North Korea through the methodology of an event study, the market prices of oil products were only temporarily affected by the sanctions and remained stable over the long run despite the restrictions on the volumes of refined petroleum products introduced. This can be explained by evidence that North Korea has introduced refined oil supplies that are not much different from those before the sanctions through its use of illegal transshipments even after the sanctions. With regard to strategic materials such as refined oil, the North Korean authorities are believed to be desperately avoiding sanctions by, for instance, finding loopholes in the sanctions to meet the minimum level of demand.

Key Word: North Korean Economy, Economic Sanctions, Smuggling, Refined Oil Prices, Illegal Transshipment
JEL Code: F51, P22, P37

I. Introduction

During 2016 and 2017, North Korea conducted three nuclear tests and four missile launches, and in response, the international community strengthened its sanctions against North Korea. The sanctions are aimed at deterring North Korea from developing

* Associate Fellow, Korea Development Institute (E-mail: kyoochul@kdi.re.kr)
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nuclear weapons, and in order to achieve this, the main means are to block the inflow of foreign currency into North Korea and to ban the import of goods related to its nuclear development efforts. Specifically, the main goals of the sanctions against North Korea is to ban the exports of anthracite, processed garments, and marine products, with the goal of limiting the acquisition of foreign currency by North Korea, and to ban the import of machinery, setting a limit on the amount of oil (crude oil and refined oil products) introduced and thus hurting the North Korean economy.[1] To evaluate whether these economic sanctions were effective as a means to achieve these goals, verification of the effectiveness of sanctions against North Korea must be regarded as a very important task.

Discussions of the effectiveness of sanctions against North Korea are mainly focused on North Korea's foreign trade. The impact of sanctions, identified by trade data, is easily confirmed, with North Korea's exports amounting to $260 million in 2019, only nine percent of the $2.9 billion in 2016, just before the sanctions. Moreover, at the 2018 US-North Korea summit in Singapore, the effectiveness of sanctions was gaining strength again, as it was known that Kim Jong-un's most important request was to lift the sanctions. On the other hand, if we look at economic indicators inside North Korea, such as rice prices and market exchange rates[2] observed in informal markets there, it appears that sanctions have yet to exert any influence, as these figures, used to determine North Korea's price index, remain fairly stable even after the sanctions. Therefore, concluding that the sanctions were effective against North Korea remains controversial.

In North Korea, like other countries, oil resources are necessarily very important strategic materials. Because North Korea is not an oil-producing country, the introduction of crude oil and refined products is directly related to the stability of the North Korean regime. There have been numerous UN Security Council sanctions against North Korea, but limiting the introduction of oil is the last stage. As the sanctions against North Korea have gradually strengthened, it can be said that the international community used oil sanctions as the last resort. The oil restriction was an important issue for both North Korea and the international community, as some say that China and Russia, permanent members of the U.N. Security Council and in amicable relations with North Korea, reached an agreement only at the end.

This paper initially examines how sanctions against North Korea affected how the market prices of refined oil products (gasoline and diesel), the main items under sanction, fluctuated in North Korea. The study also hypothesizes and explains why sanctions have or have not affected the prices of refined petroleum products. According to the analysis, the prices of refined petroleum products traded in North Korea's marketplaces, though they were temporarily affected by sanctions, remained stable in the long run. This suggests that there has not been much change in long-term supply and demand levels, although there have been short-term fluctuations in oil prices due to sentimental factors for North Koreans.

[1]In addition, financial sanctions and bans on overseas workers are included, but items for people's livelihood and humanitarian purposes that are not related to nuclear and missile development are not subject to sanctions.

[2]DailyNK's homepage, a media source specializing in the situation inside North Korea, regularly provides data on North Korea's market prices for rice and informal market exchange rates (to the US dollar) on its website. The period of data recording is from August of 2009 until recently, and price data are reported 2~3 times a month (https://www.dailynk.com/english/market-trends).

If these findings are accurate, this leads to the question of how the market price of refined oil in North Korea can remain stable despite the fact that the introduction of refined oil is restricted due to the sanctions. This can be explained by annual reports by the UN Security Council's North Korea Sanctions Committee, which estimates the magnitudes of illegal transshipments of refined petroleum products. These reports suggest that even after the sanctions restricted the introduction of refined petroleum products, the amount of refined petroleum products procured by North Korea may not differ greatly from that before the sanctions. This does not mean that sanctions are completely useless or ineffective. With regard to essential strategic materials such as oil, the North Korean authorities will seek a loophole in the sanctions, which could halve their effects.

This study is organized as follows. Chapter 2 reviews recent studies on economic sanctions. Chapter 3 outlines international sanctions against North Korea and summarizes the ongoing discussion about the effectiveness of sanctions against North Korea. Chapter 4 examines data on North Korea's refined oil prices and other related variables. Chapter 5 constructs an econometric model to analyze the impact of sanctions on North Korea's refined oil prices and presents the results. Chapter 6 hypothesizes the reason for this outcome and presents supporting evidence. Chapter 7 summarizes the discussion and concludes this paper.

II. Literature Review

Thus far, sanctions a means of foreign policy have been the subject of much scholarly research. Studies that comprehensively analyzed economic sanctions show that the likelihood of successful sanctions is not very high. Hufbauer *et al.* (2009) reviewed more than 200 sanctions – finding only one-third to be successful – and explained various reasons for the failure of sanctions. Biersteker *et al.* (2013) argued that only 22% of UN sanctions can be assessed as successful. However, other studies suggest that economic sanctions are effective. Neuenkirch and Neumeier (2015) reported that sanctions imposed by the UN had a negative impact on the economic growth of 67 sanctioned countries over a long period of time through a fixed effect regression model with panel data from 1976 to 2012. As such, conclusions about the impact of economic sanctions are still mixed.

Many of the papers dealing with sanctions examined the impact of sanctions in certain economic fields. Among them, the most studied sector is foreign trade, as the main targets of economic sanctions are concentrated in foreign trade. Haidar (2017) analyzed the effects of sanctions through Iran's export data by utilizing the difference-in-difference approach using dummy variables of pre- and post-sanctions and whether or not the country was subject to sanctions. The findings showed that total exports increased, but eventually welfare losses were followed by lower prices and increased supply levels. Caruso (2003) examined the effects of economic sanctions imposed by the United States on trade over a long period of time through a panel gravity model with sanction dummy variables, showing that multilateral sanctions have a significant negative impact on trade flows. In addition, some studies analyzing the impact of sanctions have also looked at the effects on trade. Using gravity equations, Evenett (2002) confirmed that U.S. sanctions have had a major

impact, such as reducing South Africa's exports by a third. Crozet *et al.* (2020) investigated how French export firms react to sanctions through fixed-effects binary choice estimators with monthly data. Their study found an asymmetrical trade effect, demonstrating that while new sanctions reduce the probability of the entry of a company, lifting the sanctions does not immediately mean that it starts exporting. They also showed that companies with experience in exporting to countries subject to sanctions ease the impact of the sanctions, especially when the exporting company is specialized in "crisis countries," which become less affected by the sanctions. Besedeš *et al.* (2017) analyzed the effects of financial sanctions by applying a difference-in-difference method and showed that financial activity between Germany and countries subject to sanctions decreased significantly after the sanctions were activated.

The first time international sanctions against North Korea began was in 2006, and they were intended to condemn North Korea's first nuclear test and ballistic missile launch. Since then, sanctions against North Korea were instigated several times in response to North Korean military provocations, but it can be said that the sanctions against North Korea began to take effect in the second half of 2017. This occurred because China, which accounts for more than 90 percent of North Korea's trade, began to participate substantially in sanctions against North Korea starting in 2017. China was forced to adhere to the sanctions against North Korea because the clause on exceptions to people's livelihoods had been removed and the volume and quantity of items banned from trade were set. In other words, it was not until the second half of 2017 that sanctions against North Korea started to be effective, with China's participation. Therefore, despite the great interest of the international community, only three years have passed since sanctions on North Korea took effect, and though they remain an ongoing issue, there are not many studies on sanctions on North Korea at this point.

Of course, there are a number of studies on sanctions against North Korea in the period before the sanctions became effective. For example, Lee (2018) studied the impact of sanctions against North Korea on regional economic inequality in North Korea using an instrumental variable. There are also several descriptive, explanatory-based studies of the impact of sanctions imposed after 2017 on the North Korean economy, but it is difficult to find an econometric analysis. In this respect, the present study has contributed to a more rigorous examination of recent sanctions against North Korea.

This study related to work by Dreger *et al*. (2016), who studied sanctions and oil prices. An empirical analysis there showed that the depreciation in value of the Russian ruble appears to have been influenced by crude oil prices rather than by economic sanctions in the western world, raising questions about the effectiveness of sanctions. This analysis is based on cointegrated VAR models in which long-term relationships between variables are established.

The present study aims to examine the impact of sanctions against North Korea, an area that has not been studied much despite the fact that it is the most important concern of the international community at present. Sanctions against North Korea, like other economic sanctions, are designed to have a direct impact on the North Korean foreign trade sector. Rather than focusing on the overall impact of trade sanctions, however, this paper examines the effects of the embargo on petroleum

products, a major strategic material and the last resort of sanctions against North Korea. An empirical analysis is conducted using the market prices of oil products as the main variable, as these prices allow an assessment of North Korea's internal economic stability.

Depending on the field, researchers who have studied the effectiveness of sanctions thus far have used difference-in-difference methods (before and after sanctions, whether the country is subject to sanctions) or a gravity model (when the dependent variable is the amount of trade) with dummy variables. A study using price indicators (exchange rates) relied on cointegrated VAR, in which case long-term macro time-series indicators were available. However, there is no suitable control group for North Korea, and neither the major variables required for the gravity model nor the macro time-series variables are sufficient to verify the impact of sanctions on North Korea. Therefore, the effects of sanctions against North Korea on the prices of petroleum products in North Korea are investigated by means of an event study, which is a methodology that utilizes dummy variables.

III. Background of Sanctions on North Korea

A. *Overview of sanctions against North Korea*

There are two main types of sanctions imposed by the international community on North Korea. One is independent sanctions by countries such as the U.S., Japan and South Korea. The other is multilateral sanctions centered on the UN Security Council. The United States has been strengthening its sanctions recently, starting with the 2005 Banco Delta Asian Bank (BDA) financial sanctions. The major sanctions include the removal of North Korea from the international financial network, as well as secondary boycotts (businesses dealing with North Korea cannot deal with the United States). Japan has imposed its own sanctions on North Korea since the kidnapping of Japanese citizens and a nuclear test in 2006. South Korea suspended inter-Korean exchanges, except for the Kaesong Industrial Complex, in 2010 by implementing 5.24 measures due to the attack on the South Korean warship 'Cheonan', and South Korea shut down the Kaesong Industrial Complex in 2016 due to a nuclear test. Other European countries are imposing their own sanctions.

The UN Security Council sanctions against North Korea were introduced in 2006 and were strengthened in response to North Korean missile launches and nuclear tests by the end of 2017. Therefore, sanctions against North Korea were enacted with the aim of dismantling North Korea's nuclear weapons and forcing them to suspend long-range missile launches. The main means were to designate individuals and institutions linked to weapons of mass destruction as targets of sanctions and to restrict foreign trade or impose financial sanctions.

Table 1 shows the timing and contents of the UN Security Council resolutions on North Korea that have been resolved since 2013 and the reasons why the resolutions were triggered. The main reasons for the sanctions were long-range missile launches and nuclear tests, and the resolutions were approved one to three months after North Korea's actions. Many experts agree that sanctions against North Korea began to take effect in 2017, as Resolution 2321, which went into effect in December of 2016,

TABLE 1— UN SECURITY COUNCIL RESOLUTION AGAINST NORTH KOREA AFTER 2013

Classification		Date	Contents	Cause of sanction
UN Security Council Resolution	2087	Jan, 2013	Sanctions for 17 institutions and 9 individuals	Long-range missile launch in December 2012
	2094	Mar, 2013	Restrictions on North Korea's mineral trade, including coal, banning the supply of air oil and rocket fuel to the North Korea	Third nuclear test in February 2013
	2270	Mar, 2016	Export ban of coal and iron ore except for people's livelihood	Fourth nuclear test in January 2016, long-range missile in February.
	2321	Dec, 2016	Upper limit on coal exports	Fifth nuclear test in September 2016
	2356	Jun, 2017	Freezing assets, banning overseas travel, adding blacklists	Launching a Ballistic Missile in May 2017
	2371	Aug, 2017	Total ban on coal exports	July 2017, long-range missile trial launch
	2375	Sep, 2017	Upper limit of the supply of refined petroleum products (two million barrels), the freeze of the supply of crude oil	Sixth nuclear test in September 2017
	2397	Dec, 2017	Reduced supply of refined petroleum products to 500,000 barrels	Launched long-range missile in November 2017

set an upper limit on the export of anthracite, the top-ranked item among North Korean exports. Previous sanctions limited anthracite exports, but North Korea's anthracite exports have not actually been hurt due to the livelihoods exemption clause. Moreover, since 2017, China, which accounts for 90% of North Korean trade, has participated in sanctions.

UN Security Council Resolutions 2375 and 2397 are related to the introduction of crude oil and refined oil. Regarding Resolution 2375, which was determined in response to North Korea's sixth nuclear test, restrictions on oil supplies appeared for the first time. This resolution froze North Korea's crude oil imports to the current level of four million barrels, while limiting refined products to two million barrels per year. Resolution 2397, strengthened by North Korea's missile launch, was agreed upon only three months after the previous resolution. This resolution retained the supply of crude oil but reduced the supply of refined products from two million barrels to 500 thousand barrels per year.

B. *Discussions of the effectiveness of sanctions against North Korea*

Recently, there have been discussions about whether the UN Security Council sanctions against North Korea are effective, if any, and if not, for what reason. Given that North Korean sanctions mainly affect North Korea's foreign trade directly, the primary effects of North Korean sanctions can be confirmed through North Korea's trade data. Figure 1 depicts North Korea's import and export volumes between 2013 and 2019. North Korea's exports fell 38% year-on-year in 2017, when sanctions began to go into full swing, and in 2018 they decreased by 88% compared to 2017, after having already shrunk. This occurred because exports of anthracite, processed garments, and marine products, which ranked first to third among North Korean exports before the sanctions, were completely blocked by UN Security Council

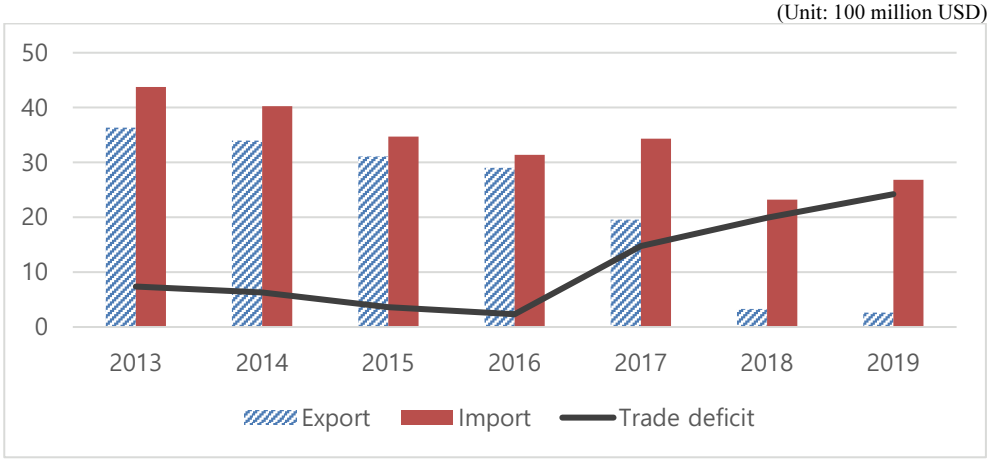


FIGURE 1. NORTH KOREA'S TRADE VOLUME AND BALANCE

Source: Korea International Trade Association.

sanctions. North Korea's imports appear to be better than its exports, but upon a closer examination of each item, imports of industrial machinery were banned, and there is an upper limit on the introduction of oil products, making it difficult to introduce intermediate goods necessary for economic activities. Moreover, a large trade deficit caused by exports falling more than imports is another challenge faced by the North Korean economy under sanctions. Before 2016, the trade deficit, which was less than $500 million, surged to $1.5 billion in 2017 and then to more than $2.4 billion in 2019.[3]

Looking at North Korea's foreign trade, sanctions appear to have a significant impact on the North Korean economy. However, when probing the indicators related to the economic situation inside North Korea, different judgements become possible. Figure 2 shows the North Korean rice market prices and market exchange rates (the exchange rate of the North Korean won against the US dollar). Since mid-2013, rice prices have fluctuated depending on the season, but they remained stable at around 5,000 KPW (North Korean won) per kg, and the exchange rate also remained at around 8,000 KPW per dollar. It is possible to consider that food, including rice, is not an item subject to sanctions, implying that imports are maintained and prices can be stabilized. Mun and Kim (2020) also showed that the exchange rate could be stabilized under sanctions on the assumption that the purposes of foreign currency are divided into value storage and trading in North Korea. As such, assessments of the impacts of sanctions on North Korea vary from sector to sector.

There remains lack of rigorous verification of the effectiveness of sanctions against North Korea, as sanctions against North Korea are still in progress, and there is also insufficient credible data to confirm the North Korean economic situation. This study examines the effects of sanctions based on reliable oil market price data from institutions that have long accumulated North Korean price data. In addition,

[3]North Korea is known to make up for its trade deficit through overseas workers. However, as sanctions against North Korea also prohibit the dispatch of workers abroad, the trade deficit, which has widened since the sanctions, is likely to remain an unresolved issue.

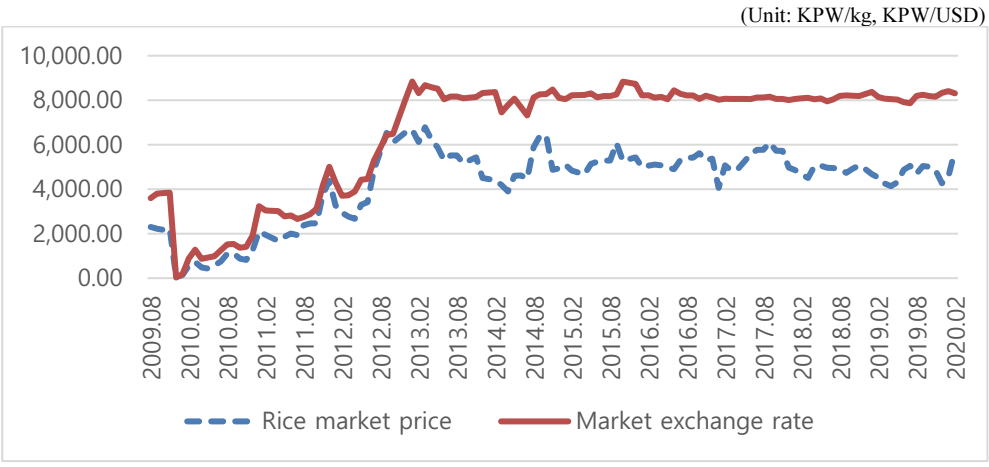


FIGURE 2. RICE MARKET PRICE AND MARKET EXCHANGE RATE IN NORTH KOREA

Source: DailyNK.

the study examines the effect of 'smart sanctions' that limit the import of certain items on the economy by focusing on refined oil products, which are important items of sanctions.

IV. Data

A. *Market price data for oil products in North Korea*[4]

The price data of North Korea's refined oil products to be used in this study are the market prices of gasoline and diesel traded in the '*Jangmadang*' (informal marketplace). DailyNK, specialized media targeting North Korea, regularly publishes figures on dollar exchange rates and the prices of major goods (e.g., rice, refined oil) traded in marketplaces in North Korea's three regions (Pyongyang, Sinuiju, and Hyesan) on the web page "North Korea Market Trends."[5] The refined oil data used in this study are monthly price data from September of 2010 to November of 2018.

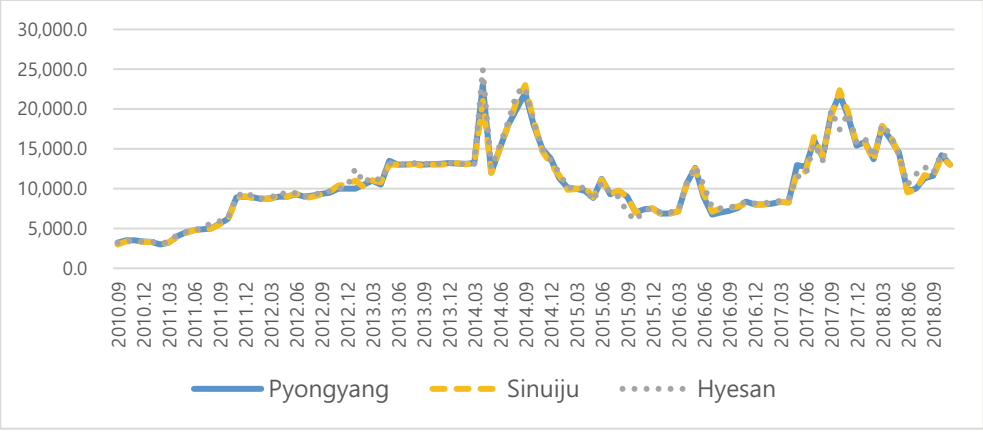
At this point, we examine the price trends of gasoline and diesel traded in North Korean markets. Figure 3 shows the market prices of gasoline and diesel (based on the North Korean won). First, it can be seen that gasoline and diesel prices in Pyongyang, Sinuiju, and Hyesan do not vary significantly by region. Sinuiju and Hyesan are the center cities of trade bordering China, and Pyongyang, as the North Korean capital, serves as North Korea's center not only in politics but also in

[4]The prices in the marketplace used in this study were collected by DailyNK, a South Korean newspaper, rather than by North Korea's statistics authorities or authorized agencies. Despite this limitation, DailyNK's market price data are most widely used domestically and internationally as data to assess North Korea's price levels and are recognized as reliable figures in that they are fairly similar to those by Asia Press, another media outlet related to North Korean that announces prices in North Korea, thus enabling us to double-check the figures.

[5]https://www.dailynk.com/english/market-trends

[1. Gasoline]

(Unit: KPW/kg)



[2. Diesel]

(Unit: KPW/kg)

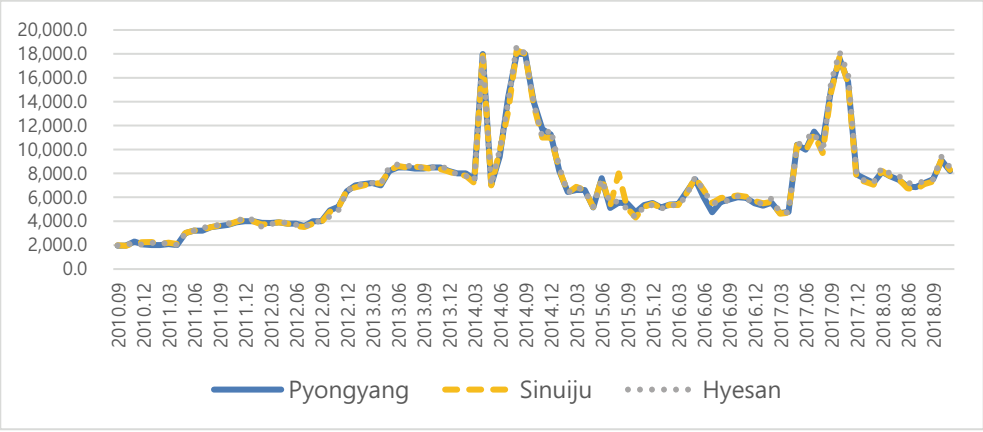


FIGURE 3. NORTH KOREA'S GASOLINE AND DIESEL MARKET PRICES (NORTH KOREAN WON)

Source: DailyNK.

economics. The coincidence of the market prices of gasoline and diesel in major cities in North Korea means that North Korea's transportation and communication methods have been developed efficiently and demonstrate the law of one price.

Second, the price trend is as follows. Gasoline and diesel prices, which were 3,000~3,500 KPW and 1,950~2,200 KPW in mid-2010, respectively, rose steadily and recorded levels of 13,000 KPW and 8,500 KPW in mid-2013. This is nearly a quadrupling of the price of oil products in three years. From 2010 to mid-2013, North Korea experienced severe inflation, making it difficult to see this as a characteristic of refined oil prices. As shown in Figure 2, during this period, rice prices and exchange rates also skyrocketed; in November of 2009, North Korean authorities implemented a currency reform that set an upper limit on exchange amounts. As a result, North Koreans' trust in North Korean currency was greatly reduced, and dollarization started to increase. It wasn't until 2013 that market prices and exchange

rates became stable. Those who study North Korea believe that stabilizing prices and foreign exchange rates have been the most notable economic phenomena since Kim Jong-un took power.

From the second half of 2013 to the beginning of 2014, both gasoline and diesel prices stabilized, but by April of 2014, gasoline and diesel prices had doubled in all regions of Pyongyang, Sinuiju and Hyesan. In May of that year, prices returned to the March level but began to rise again in June, peaking in September, after which prices started to fall. The sharp rise and drop in gasoline and diesel market prices in 2014 appears to be related to rumors of China's cessation of crude oil supply to North Korea. According to Chinese customs statistics, by 2013 China had provided approximately 520 thousand tons (four million barrels) of crude oil annually to North Korea. However, since 2014, China's crude oil exports to North Korea have been confirmed to have been officially absent. At the time (the first half of 2014), opinions were divided as to whether China actually stopped exporting crude oil to North Korea or changed the form of trade from commodity trading to aid. Although China has not yet recorded crude oil exports to North Korea in their customs statistics, it is highly likely that North Korea has introduced crude oil from China since 2014 as before. China's customs statistics still show no crude oil exports to North Korea, but a recent report to the U.N. Security Council showed that China supplied four million barrels of crude oil to North Korea. Based on this, it can be said that China has not stopped supplying crude oil to North Korea since 2014. However, the skyrocketing market prices of gasoline and diesel in North Korea in 2014 show that North Korean's sentiments were reflected in this background. According to media reporting on the lives of North Koreans at that time, it appears that North Korean military training was reduced due to the lack of oil supplies or that individual hoarding was widespread due to difficulties in introducing crude oil from China.

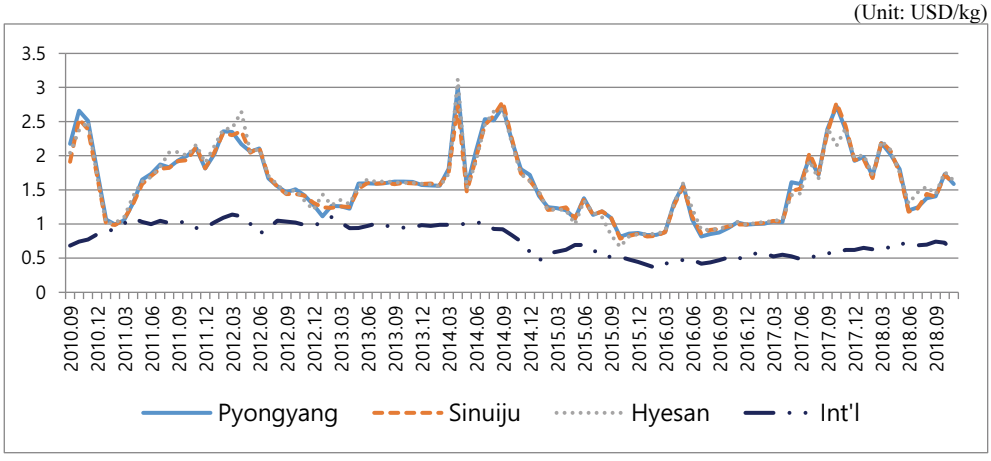
From 2015 to early 2017, there were several price hikes, but lower than the volatile period in 2014. Since mid-2017, prices have soared again to the level of 2014, later entering a downward trend, staring in October 2017. In the second half of 2017, when the UN Security Council resolution on North Korea was announced, the price of refined oil in North Korea started to be affected.

Refined petroleum products have greater homogeneous merchantability than other manufactured goods or services, making it easier to compare their international prices. Therefore, if the market prices of petroleum products in North Korea are converted into US dollars and compared to the international market price, it will become possible to grasp a different meaning from that analyzed by the North Korean won standard. Figure 4 shows North Korea's monthly gasoline and diesel market prices converted into US dollars and compared to international prices. The international price is the price of petroleum products traded in Singapore, with values of 92RON for gasoline and 0.05% for diesel.

Figure 4 clearly shows that North Korea's market prices for both gasoline and diesel are unstable compared to international prices. In addition, both gasoline and diesel are priced higher than in international markets, although there are some exceptions. From September of 2010 to November of 2018, North Korea's monthly market prices averaged 2.15 times higher for gasoline and 1.53 times higher for diesel than international prices. The largest gap between North Korea's market prices and international prices was in October of 2017, when gasoline was 4.46

[1. Gasoline]

(Unit: USD/kg)



[2. Diesel]

(Unit: USD/kg)

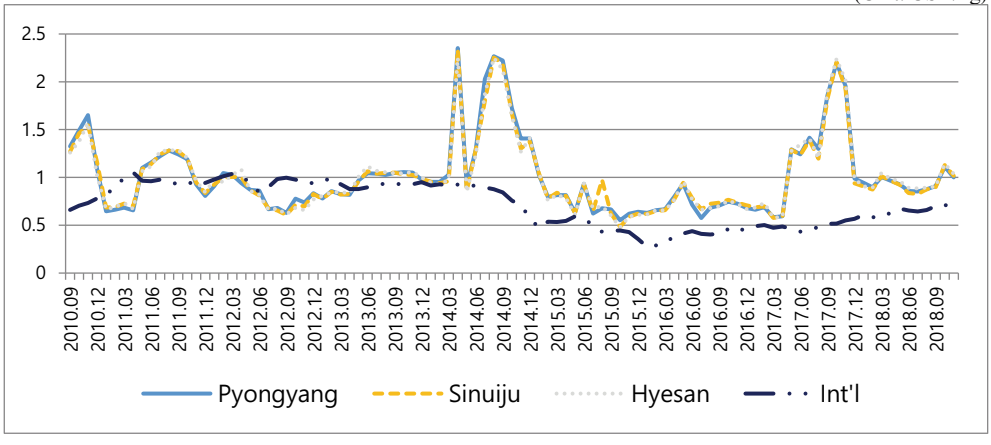


FIGURE 4. NORTH KOREA'S GASOLINE AND DIESEL MARKET PRICES AND INTERNATIONAL PRICES

Source: DailyNK; Korea National Oil Corporation (international) (http://www.opinet.co.kr/user/main/mainView.do)

times and diesel was 4.29 times more. Given that international prices are sourced from Singapore's oil spot market, it is common for prices to be lower than those in North Korea, as the latter can be referred to as consumer prices. Nonetheless, it can be considered abnormal that they are different by more than four times. This is believed to have been influenced by the adoption of UN Security Council Resolution 2375 on September 12, 2017, for the first time reflecting restrictions on oil supplies to North Korea. As such, international sanctions against North Korea may have had some impact on the North Korea's refined oil prices.

In addition, it can be seen that the degree of disparity between North Korea's market price and international price varies depending on the oil type. From mid-2014 to the end of the year and from mid-2017 to early 2018, the market prices of gasoline and diesel both skyrocketed, leading to a wide gap with international prices. However, from 2011 to 2012, only the market price of gasoline soared, becoming

higher than the international market price, whereas the market price of diesel did not show much of a difference from the international market price. As such, whether the North Korean oil market price was actually influenced by sanctions or other factors will be examined in detail in the following sections.

B. *Determinants of refined oil products prices in North Korea*

What factors will affect North Korea's oil prices? In order to confirm the impact of North Korean sanctions in this study, appropriate control of variables that can also affect the prices of petroleum products is necessary.

Factors that determine gasoline and diesel prices in North Korean marketplaces can be divided into demand, supply and other factors. The demand-side factors include oil demand from the North Korean military, such as for military training and military operations; industrial demand for plant operations and power generation; and the demand for oil products from the private sector, including vehicles such as buses and trucks. On the supply side, China's export price of refined oil, the export volume, and supply through crude oil refining can affect the price of oil in North Korea. Other factors include North Korea's market exchange rate, their economic situation, and their development of oil-related technologies. In addition, external shocks such as sanctions against North Korea are factors that could affect oil prices in the country. However, due to the nature of the research subject here, North Korea, available data is scant. Among the variables expected to affect the prices of petroleum products, available data include the rice market price, the market exchange rate, North Korea's gasoline/diesel import prices, and North Korea's gasoline/diesel import volumes.[6]

Rice market prices and exchange rates are the most widely used indicators of prices in North Korean economic research. As shown in Figure 2, the North Korean rice price has skyrocketed since the currency reform in 2009. Stabilized rice market prices and exchange rates since 2013 are considered to be evidence that North Korea's prices have stabilized significantly since Kim Jong-un took power.

Because North Korea is not an oil-producing country and is forced to rely on imports, the prices of refined petroleum products are bound to be affected by the volume of imports and import prices. Therefore, North Korea's refined product import volume and unit price were used as control variables, with Chinese customs statistics providing these data. According to the customs statistics, China has not exported gasoline or diesel to North Korea since October of 2017. Instead, the UN Security Council's North Korea Sanctions Committee provides information on the monthly volume introduced by North Korea since October of 2017 because Resolution 2375 requires a country that supplies refined products to North Korea to report these transactions. However, while information about supply amounts is provided, information about the unit price is not available. To understand the impact of sanctions on North Korea's prices of refined oil products after October of 2017,

[6]Data related to North Korea's consumption of refined products (training numbers from the North Korean military, consumption of oil by the private sector) and data related to supply (supply through crude oil refining) were not available and could not be used as control variables in the analysis. Instead, it is considered that these variables are not likely to have changed significantly over time. Thus, the analysis is performed under the assumption that they can be treated as constants.

data on the import prices of refined products after this point are required. We decided to use the average export price of China to the world instead of the export price to North Korea for refined products because the correlation coefficient between these variables is very high, at 0.84, and the relationship between the two variables is well maintained linearly for the entire period.

Lastly, external factors such as sanctions are factors that can affect North Korea's oil product prices. The UN Security Council sanctions against North Korea, as shown in Table 1 above, appear to have had a direct impact on the North Korean economy and would naturally have affected oil prices. However, considering that the time interval between sanctions is not very long, it is not easy to identify the effect of each sanction on the prices of petroleum products. Moreover, North Korean economic agents may have reacted in advance in anticipation that sanctions would follow if North Korean authorities conducted nuclear tests or missile launches. Therefore, in this study, sanctions are divided into three categories according to the time period. The classification criteria were set as one sanction group when the time interval between sanctions was six months or less. According to this standard, the UN Security Council sanctions against North Korea listed in Table 1 are classified into Group 1 (2087 and 2094), Group 2 (2270), and Group 3 (2321, 2356, 2371, 2377, 2397).

V. Empirical Analysis

A. *Econometric model*

Based on the data mentioned, the following econometric model is constructed to analyze the impact of sanctions on the market prices of oil products in North Korea. We build panel data using monthly data from September of 2010 to November of 2018 in Pyongyang, Sinuiju and Hyesan. Therefore, the panel model below is used for the analysis. It uses the aforementioned event study methodology as a means by which to check whether certain events, in this case sanctions against North Korea, affect economic variables. The event study methodology is widely used in financial sector research. It is commonly applied to research that analyzes the effects of certain news items on stock prices, and regarding North Korea, studies such as the effects of nuclear tests and missile launches on the South Korean stock market (Kim and Roland, 2014) are representative papers that apply the event study methodology.

$$y_{i,t} = X_{i,t}\beta + \alpha_i + CAR_1 + e_{i,t} \qquad if\ t = 1$$
$$y_{i,t} = X_{i,t}\beta + \alpha_i + CAR_t - CAR_{t-1} + e_{i,t} \qquad if\ t > 1$$

In the equation above, the subscript i denotes the region and, t is the point in time, $y_{i,t}$ is the value logged as the gasoline/diesel market price in i region, and t refers to the time. $X_{i,t}$ represents control variables, including the market price of rice (log), the market exchange rate (log), the price of China's gasoline/diesel exports (log), and the amount of North Korea's gasoline/diesel imports to China. α_i

refers to fixed effects that reflect the characteristics of the region. CAR is an abbreviation of cumulative abnormal return, referring to the sum of AR (abnormal return). AR refers to abnormal returns that are not explained by common variables such as excess earnings or losses in the stock market. AR_1, which is the abnormal rate of return for the first period, is equal to CAR_1, and the abnormal rate of return AR_t for the t (>1) period is expressed as $CAR_t - CAR_{t-1}$. However, in the above model, the dependent variable $y_{i,t}$ indicates the North Korean oil price in market, not the stock price. In other words, North Korea's gasoline/diesel prices are affected by special events such as sanctions, in addition to the general economic variables (e.g., rice prices, exchange rates, the volume of import, import prices) that affect it, and they appear as AR. In this study, the above equation is modified as follows to examine the short-term effects from five months before the event occurs to five months after the event occurs.

$$y_{i,t} = X_{i,t}\beta + \alpha_i + \sum_{t=-5}^{5} \theta_{kt} D_{k(T_k+t)} + e_{i,t}$$

In this equation, k is an event affecting the price of refined oil in North Korea, and T_k indicates the time when the event k took place. The values of the dummy variables $D_{k(T_k-5)}$ to $D_{k(T_k+4)}$ are 1 at the time of event T_k+t, -1 at T_k+t+1 and 0 otherwise. The last dummy variable, $D_{k(T_k+5)}$, has a value of 1 during T_k+t and 0 for the rest of the time. Using these dummy variables, we can observe the impact from five months before to five months after the occurrences of events affecting oil prices. As described in Chapter 4 above, North Korean sanctions were divided into three groups. Therefore, the observation period of each sanction group was set from five months before the first sanction in the group to five months after the last sanction in the group.

Through the panel data, a pooled OLS model, a fixed effect model, and a random effect model can be used. Among these, prior verification is essential to adopt the most suitable methodology. The best option for the pooled OLS model is when the variance of α_i, a characteristic of each region, is zero. In other words, the regional characteristics of Pyongyang, Sinuiju and Hyesan do not differ much, and it can be confirmed that the actual market price of gasoline/diesel, the market price of rice, the exchange rate do not differ by region. In addition, the results of the LM test (Breusch and Pagan, 1979) do not reject the hypothesis that the variance of α_i is zero, leading to the conclusion that using a pooled OLS model is preferable to using a fixed-effects model. The Hausman test results also show that the pooled OLS model is the most appropriate methodology because the coefficients derived from the fixed-effect model and the random-effect model are not significantly different. The subsequent discussion therefore proceeds on the basis of the pooled OLS model.

B. *Analysis of estimation results*

In this chapter, the results of the event study estimation equation above are presented and analyzed. Below is shown a figure of the impact of sanctions on North Korea on the market prices of refined petroleum products. Detailed estimation results, such as the coefficient values of various control variables, can be confirmed through the table in the appendix.

As previously classified, the sanctions against North Korea were divided into three groups according to the timing, and the month in which the UN Security Council imposed sanctions on the North Korea is marked with red square blocks in Figure 5. The y-axis in the figure represents the abnormal return (the coefficient in the table in the appendix is the cumulative abnormal return (CAR), and the number in Figure 5 is calculated as $CAR_t - CAR_{t-1}$) for the prices of oil products in North Korea, which are confirmed after controlling for other explanatory variables. A high value of AR means that the abnormal portion of the price of refined petroleum products that is not explained by other control variables is large, which is indicative of the influence of sanctions against North Korea. This positive value means that sanctions on North Korea served to increase the prices of refined petroleum products.

The sanctions in 2013, classified as Group 1, appeared to have had little impact on North Korea's refined oil prices. UNSCR 2270 (group 2), agreed upon in March of 2016, was a factor in the increasing gasoline prices, but the impact on diesel was relatively small. Moreover, the effect on gasoline prices also disappeared after three to four months. The sanctions that have greatly affected both gasoline and diesel prices are Group 3 sanctions after 2017. Abnormal return (prices) for gasoline and diesel due to sanctions have been outstanding for both types since May of 2017, when North Korea launched a ballistic missile, which led to the adoption of UN Security Council Resolution 2356 in June. Subsequently, three more sanctions against North Korea were resolved by the end of 2017, resulting in very high prices

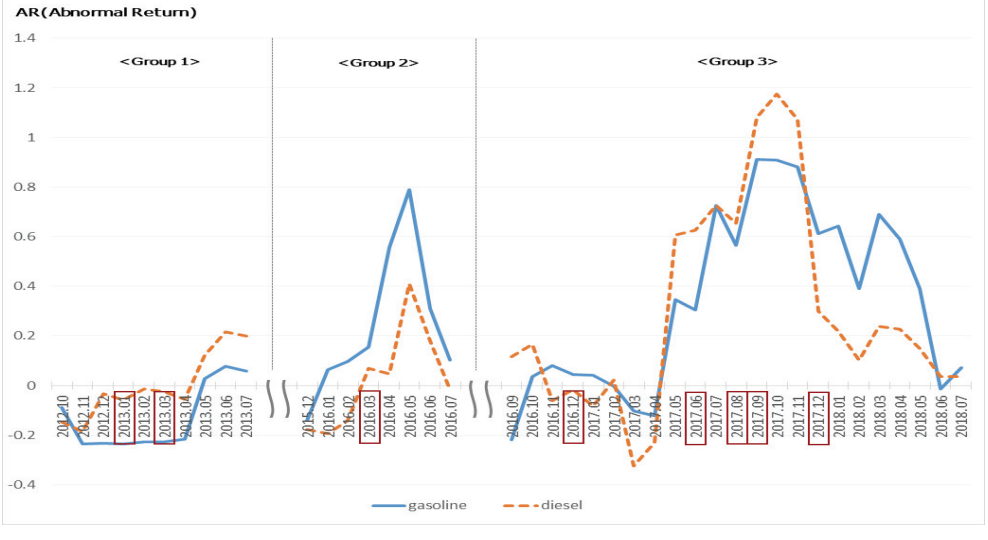


FIGURE 5. IMPACT OF SANCTIONS ON THE PRICES OF REFINED OIL IN THE NORTH KOREAN MARKET

for gasoline and diesel, but the situation has not lasted long since 2018. According to Figure 5, gasoline prices were affected until the first half of 2018, but diesel appears to have been affected by sanctions until 2017. In other words, after the sanctions in 2017, the prices of refined products increased significantly in the short term, but the period was not long, and the prices recovered to their levels before the sanctions in 2017.

These results indicate that the price fluctuations in North Korea's petroleum products due to sanctions are attributed to sentimental factors of North Koreans, such as hoarding. There has been news that the stockpiling of oil products occurred immediately after sanctions but that the prices stabilize to the level before sanctions because the total quantity supplied to North Korea was secured through the smuggling of petroleum products. In conclusion, with the exception of price fluctuations due to the psychology of North Koreans, the market prices of gasoline and diesel in North Korea have remained constant without much change, meaning that the impact of sanctions on the prices of refined petroleum products has been short-lived.

The impact of other control variables[7] on the prices of gasoline and diesel in North Korea is as follows. First, the increase in market exchange rates increased the market prices for gasoline and diesel. This is consistent with intuition, in that both gasoline and diesel are not produced in North Korea and must therefore be imported from foreign countries, and prices of oil products must be positively influenced by exchange rates. Second, the market price of rice does not affect the price of gasoline, but it has a negative correlation with the price of diesel. Considering that diesel is used for transportation, such as buses and cargo trucks, and that gasoline is used for general passenger cars in North Korea, a decrease in rice prices means an increase in the demand for rice, which increases the demand for transportation and logistics vehicles such as trucks, which could lead to an increase in the market price of diesel. Therefore, it can be interpreted that the price of rice only affects the price of diesel, which is the fuel of trucks, and does not affect the price of gasoline, required for private vehicles only for political elites, especially in North Korea. Third, the export price of petroleum products in China, which was used as a proxy variable for North Korea's import price, has a positive effect on both gasoline and diesel market prices. North Korea’s gasoline and diesel import prices (≈ China’s export prices) are the benchmark prices of gasoline and diesel sold in the market; hence, the export price and market price must be closely linked. In addition, gasoline and diesel import volumes had a positive effect on each market price, but the coefficient value was very close to zero, meaning that the effect appears to be negligible. In general, assuming that all other conditions are the same, the price will fall if the quantity of imported goods increases. However, the import data of gasoline and diesel used in this estimation are official data gained through the customs agency and do not include smuggling or crude oil refining in North Korea. Given evidence that smuggling levels exceed the official volume, which will be addressed in the next chapter on the smuggling volume of petroleum products, the result here appears to be reasonable given that the official import volumes have scant effects on the market prices.

[7]See the appendix for specific coefficient values of the control variables.

VI. Discussion of the limited impact of sanctions

Summarizing the findings above, despite restrictions on the introduction of petroleum products into North Korea, internal prices have only been shocked in the short term but have stabilized over the long term. Naturally, one can't help but wonder, "Why is the market price of refined oil in North Korea stable despite the fact that sanctions restrict the introduction of oil?" In this regard, we can hypothesize that North Korea's oil supply is maintained despite sanctions.[8] We borrow the discussion of the annual reports of the UN Security Council Sanctions Committee on North Korea to verify this hypothesis. These reports detail North Korea's smuggling of refined petroleum products. It is widely known that smuggling was active in the border area between North Korea and China even before the sanctions. However, it appears that wider and more diverse forms of smuggling have been spreading as the UN Security Council strengthens its sanctions against North Korea. The smuggling of refined oil is carried out through transshipments in international waters. These volumes are not dealt with through customs but are illegal, which explains why they are of course not recorded in official statistics.

Official reports from the governments of the Republic of Korea (South Korea) and the US provided information about the total volume of refined oil products introduced by North Korea prior to sanctions. The Ministry of Foreign Affairs of South Korea[9] and the U.S. Mission to the United Nations[10] estimate that the total amount of refined petroleum products introduced by North Korea in 2016 reached 4.5 million barrels (about 600 thousand tons[11]), respectively.

Given that the two countries' officially announced that the introduced levels of refined products in North Korea are identical, it is appropriate to regard the amount of refined oil introduced in North Korea as 4.5 million barrels before the sanctions. The amount of refined oil officially introduced by North Korea through customs in 2016 is 278 thousand tons. Therefore, if smuggling is regarded as the total introduced amount of 600 thousand tons minus the official introduction amount of 278 thousand tons through customs, the amount of refined oil introduced by North Korea through smuggling can be estimated to be more than 300 thousand tons. This means that the amount of refined oil introduced through smuggling even before the sanctions is significant.

[8]It is also possible to hypothesize that the consumption of petroleum products in North Korea has decreased since the sanctions. This means that the North Korean military's training may have decreased in preparation for sanctions, or the demand for transportation has decreased due to the sanctions. In this regard, there is anecdotal evidence such as news that the demand for transportation has decreased due to coal export sanctions or that military training has been reduced, but these effects are difficult to verify numerically in the absence of relevant data.

[9]South Korea`s foreign ministry reported in a press release that imposing an annual cap of two million barrels of oil to North Korea would cut about 55 percent of its oil products. "U.N. Security Council Resolution 2375 Adopts Sanctions on North Korea" (http://www.mofa.go.kr/www/brd/m_3976/view.do?seq=366621&srchFr=&srchTo=&srchWord=&srchTp=&multi_itm_seq=0&itm_seq_1=0&itm_seq_2=0&company_cd=&company_nm=,).

[10]"Fact sheet: U.N. Security Council Resolution 2397" of the U.S. Embassy and consulate in Korea reported, "In 2016, 4.5 million barrels (about 600,000 tons) of oil were imported by North Korea" (https://kr.usembassy.gov/ko/122217-fact-sheet-un-security-council-resolution-2397-north-korea-ko/).

[11]Regarding refined petroleum products, the density varies by type. Thus, when converted from barrels in volume to tons in weight, a difference occurs depending on the type. Because 4.5 million barrels of refined petroleum products can be considered to be approximately 530 to 670 thousand tons, the median was assumed to be 600 thousand tons. When converting barrels into tons, refined petroleum products are generally divided by 7.6, a value which, if applied, is calculated to be 592 thousand tons.

The UN Security Council Sanctions Committee on North Korea publishes annual reports on the implementation of sanctions, and these provide information about North Korea's introduction of illegal refined oil in the face of sanctions. Two annual reports in 2019 and 2020 contain information about the names and capacities of tankers entering and leaving from Nampo port (North Korea's largest port, near Pyongyang). In addition, the reports calculate estimates of the oil products introduced by North Korea through illegal transshipments, assuming that 33 percent, 50 percent and 90 percent of the total capacity is loaded. Table 2 summarizes the relevant contents. The 2019 report provides information about a total of 148 illegal transshipments during the period from January to August of 2018, mentioning also that the frequency of transshipments has increased since September. According to the three scenarios regarding capacity ratings, it is estimated that North Korea smuggled approximately 110~300 thousand tons of refined oil products during this period.[12] If the period is simply extended proportionally until December, the volume introduced through illegal transshipments is estimated to be between 150 thousand tons and 400 thousand tons. If the official amount of 48 thousand tons[13] is added, the amount of refined petroleum products introduced by North Korea in 2018 would reach between 200 thousand and 450 thousand tons.[14] The 2020 report contains illegal transshipment information from January to October of 2019. Calculating identically to the 2018 figures, the volume of refined petroleum products introduced by North Korea in 2019 is estimated to be 290 to 670 thousand tons. Assuming that tankers were operating at 90 percent capacity, this means that the amount of refined oil introduced by North Korea has not decreased significantly compared to the approximate level of 600 thousand tons, i.e., the pre-sanction amount.

This is believed to be strong evidence that prices of North Korean refined petroleum products have not been significantly affected despite sanctions on oil import restrictions. After the sanctions, the introduction of refined products through informal channels such as smuggling increased significantly, and the North Korean authorities appear to be desperate to meet the minimum oil demand required to run the economy. This does not mean that sanctions against North Korea have not had all of their intended effects. As noted earlier, North Korea's foreign trade has reached the level of collapse since the sanctions. In addition, it is the lifting of sanctions that North Korean authorities most desperately wanted during the two former U.S.-North

[12]Based on this, the U.S. representative to the United Nations claimed the amount of refined oil introduced to North Korea has exceeded the limit, but Russia and China argued that the U.S. estimate of North Korea's illegal transshipments is only fragmentary information and cannot be confirmed as a violation of sanctions because it is not conclusive evidence.

[13]The U.N. Security Council's sanctions committee's website contains information about the amount of refined oil introduced into North Korea in an official manner since October of 2017. This provides information about the amounts of North Korea's official refined oil imports (https://www.un.org/securitycouncil/sanctions/1718/supply-sale-or-transfer-of-all-refined-petroleum).

[14]The estimated total introduced volume in 2018 was significantly reduced compared to the 600 thousand tons introduced in 2016, before the impact of the sanctions. This estimate is when the introduced amount from January to mid-August of 2018 was simply extended to December. According to the report, the frequency of smuggling increased significantly in the second half of the year. Therefore, the actual smuggling volume in 2018 is likely to be greater than the figure estimated in this study. The demand for petroleum products would have also declined due to sanctions. As exports of North Korea's major export items such as anthracite were banned due to sanctions against North Korea, it is highly likely that the demand for transportation from mines to ports also decreased. In addition, as sanctions have reduced economic activity in North Korea's marketplace, the demand for transportation between markets across the country may have also declined. These factors imply that prices are only affected in the short term, despite the fact that estimates of the introduction of refined products in 2018 have decreased.

TABLE 2— ESTIMATES OF NORTH KOREA'S INTRODUCTION OF REFINED OIL PRODUCTS

	2019 Report	2020 Report
Period	January to mid-August, 2018	January to October, 2019
Number of illegal transshipments	148	221
Total capacity of tankers	2.5 million barrels (330 thousand tons)	4.32 million barrels (570 thousand tons)
33% capacity	0.83 million barrels (110 thousand tons)	1.44 million barrels (190 thousand tons)
50% capacity	1.25 million barrels (160 thousand tons)	2.16 million barrels (280 thousand tons)
90% capacity	2.27 million barrels (300 thousand tons)	3.89 million barrels (510 thousand tons)
Extended to December (33~90%)*	1.17~3.2 million barrels (150~400 thousand tons)	1.73~4.67 million barrels (230~610 thousand tons)
Official introduction**	48 thousand tons	56 thousand tons
Final estimate***	200~450 thousand tons in 2018	290~670 thousand tons in 2019

Note: Based on the UN Security Council's North Korea Sanctions Committee report, *Values extended to December (33 to 90%) are calculated in simple proportion to December, **The official introduction amount is quoted by the United Nations Security Council's North Korea Sanctions Committee, ***The final estimate is the sum of the figures extended to December and the official introduction.

Korea summits in 2018 and 2019. As such, sanctions against North Korea appear to have some effect. On the other hand, it seems that North Korean authorities' attempts to bypass or avoid sanctions will continue with regard to strategic materials such as petroleum, which are directly related to the maintenance and stability of the regime.

VII. Conclusion

The international community's sanctions against North Korea triggered by North Korea's nuclear tests and missile launches are regarded as unprecedentedly strong sanctions in history. North Korea's major exports were banned, leading to the collapse of the country's exports, which is expected to cause problems in its foreign currency supply if the situation continues to escalate. However, rice prices and exchange rates observed in North Korea's informal markets, which illustrate the economic situation inside the country, have been confirmed to be fairly stable even after the sanctions. Many experts predict that as the sanctions continue, prices and market exchange rates are also likely to become unstable.

This study examined the market price fluctuations of refined products, the main embargo item and target of the sanctions on North Korea. Immediately after the sanctions against North Korea commenced, the market prices of gasoline and diesel temporarily skyrocketed, reflecting North Koreans' sentiment that the oil supply will be limited. However, sanctions only temporarily affected the prices of North Korean refined oil products, with gasoline and diesel returning to their old prices within a few months. Despite the fact that the amount of refined oil introduced due to sanctions has been drastically reduced, price stability can be seen as a type of puzzle. A clue to this can be found in an annual report by the UN Security Council Sanctions Committee on North Korea.

The reports by the UN Security Council's North Korea Sanctions Committee

calculate the estimated quantities of refined petroleum products introduced by North Korea through illegal transshipments and disclose information on these amounts. Based on this data, it is possible that North Korea's import volumes of refined oil have not changed much despite the sanctions.

However, this analysis does not entirely deny the effectiveness of sanctions against North Korea. Energy sources such as oil are directly related to the stability and maintenance of the North Korean regime, meaning that North Korean authorities are likely to be more sensitive to these than to other items. Therefore, despite strong sanctions, the North Korean authorities appear to find loopholes, such as the smuggling of refined petroleum products.

APPENDIX

TABLE A1— ESTIMATION RESULTS OF THE EVENT STUDY EQUATION

(a) Gasoline

Variables		Group 1	Group 2	Group 3
Log (Foreign exchange rate)		0.668***	0.820***	0.857***
		(0.117)	(0.0955)	(0.0911)
Log (Rice price)		0.0951	0.0345	0.0237
		(0.130)	(0.0986)	(0.0952)
Log (China export price)		0.855***	0.951***	0.854***
		(0.193)	(0.0639)	(0.0712)
Import volume		7.48e-06	1.58e-05***	1.29e-05***
		(5.94e-06)	(3.61e-06)	(3.62e-06)
Group 1 (CAR)	2020.09	-0.205*	-0.327***	-0.318***
		(0.122)	(0.118)	(0.112)
	2020.10	-0.293	-0.477***	-0.485***
		(0.186)	(0.174)	(0.164)
	2012.11	-0.528**	-0.838***	-0.844***
		(0.236)	(0.221)	(0.208)
	2012.12	-0.761***	-1.150***	-1.180***
		(0.282)	(0.260)	(0.245)
	2013.01	-0.996***	-1.524***	-1.565***
		(0.323)	(0.295)	(0.278)
	2013.02	-1.224***	-1.866***	-1.925***
		(0.362)	(0.327)	(0.307)
	2013.03	-1.450***	-2.210***	-2.284***
		(0.403)	(0.361)	(0.339)
	2013.04	-1.666***	-2.521***	-2.620***
		(0.441)	(0.391)	(0.368)
	2013.05	-1.639***	-2.588***	-2.716***
		(0.479)	(0.419)	(0.393)
	2013.06	-1.562***	-2.623***	-2.775***
		(0.512)	(0.443)	(0.416)
	2013.07	-1.503***	-2.702***	-2.870***
		(0.546)	(0.467)	(0.438)

TABLE A1— ESTIMATION RESULTS OF THE EVENT STUDY EQUATION (CONT'D)

(a) Gasoline

Variables		Group 1	Group 2	Group 3
Group 2 (CAR)	2015.11		-0.265**	-0.321***
			(0.116)	(0.113)
	2015.12		-0.407**	-0.533***
			(0.170)	(0.171)
	2016.01		-0.343	-0.577***
			(0.216)	(0.217)
	2016.02		-0.246	-0.584**
			(0.266)	(0.270)
	2016.03		-0.0899	-0.524
			(0.317)	(0.330)
	2016.04		0.467	-0.0639
			(0.369)	(0.393)
	2016.05		1.258***	0.617
			(0.420)	(0.450)
	2016.06		1.568***	0.840*
			(0.466)	(0.505)
	2016.07		1.672***	0.840
			(0.512)	(0.554)
Group 3 (CAR)	2016.08			-0.0420
				(0.112)
	2016.09			-0.262
				(0.182)
	2016.10			-0.226
				(0.237)
	2016.11			-0.144
				(0.288)
	2016.12			-0.0984
				(0.335)
	2017.01			-0.0575
				(0.371)
	2017.02			-0.0605
				(0.410)
	2017.03			-0.164
				(0.453)
	2017.04			-0.285
				(0.494)
	2017.05			0.0617
				(0.532)
	2017.06			0.367
				(0.572)
	2017.07			1.092*
				(0.612)
	2017.08			1.657**
				(0.652)
	2017.09			2.567***
				(0.695)
	2017.10			3.477***
				(0.734)

TABLE A1— ESTIMATION RESULTS OF THE EVENT STUDY EQUATION (CONT'D)

(a) Gasoline

Variables		Group 1	Group 2	Group 3
Group 3 (CAR)	2017.11			4.357***
				(0.775)
	2017.12			4.968***
				(0.808)
	2018.01			5.610***
				(0.842)
	2018.02			6.000***
				(0.869)
	2018.03			6.691***
				(0.897)
	2018.04			7.280***
				(0.927)
	2018.05			7.672***
				(0.954)
	2018.06			7.659***
				(0.979)
	2018.07			7.732***
				(1.005)
Constant		-3.326***	-4.767***	-4.303***
		(1.126)	(0.516)	(0.544)
Observations		129	222	297
R-squared		0.882	0.860	0.877
Standard errors in parentheses			*** p<0.01, ** p<0.05, * p<0.	

(b) Diesel

Variables		Group 1	Group 2	Group 3
Log (Foreign exchange rate)		1.025***	1.299***	1.354***
		(0.123)	(0.134)	(0.121)
Log (Rice price)		-0.188	-0.325**	-0.377***
		(0.128)	(0.137)	(0.125)
Log (China export price)		0.0578	0.551***	0.591***
		(0.253)	(0.0824)	(0.0869)
Import volume		5.41e-06	1.87e-05***	1.86e-05***
		(3.83e-06)	(4.41e-06)	(3.96e-06)
Group 1 (CAR)	2020.09	-0.340***	-0.510***	-0.498***
		(0.126)	(0.164)	(0.147)
	2020.10	-0.488**	-0.725***	-0.707***
		(0.191)	(0.244)	(0.219)
	2012.11	-0.673***	-1.036***	-1.018***
		(0.244)	(0.310)	(0.279)
	2012.12	-0.705**	-1.221***	-1.206***
		(0.292)	(0.369)	(0.332)
	2013.01	-0.764**	-1.440***	-1.432***
		(0.337)	(0.420)	(0.378)
	2013.02	-0.779**	-1.653***	-1.652***
		(0.378)	(0.465)	(0.418)
	2013.03	-0.803*	-1.881***	-1.883***
		(0.425)	(0.511)	(0.459)

TABLE A1— ESTIMATION RESULTS OF THE EVENT STUDY EQUATION (CONT'D)

(b) Diesel

Variables		Group 1	Group 2	Group 3
Group 1 (CAR)	2013.04	-0.859*	-2.172***	-2.182***
		(0.469)	(0.551)	(0.495)
	2013.05	-0.737	-2.251***	-2.271***
		(0.506)	(0.589)	(0.529)
	2013.06	-0.521	-2.174***	-2.206***
		(0.542)	(0.624)	(0.560)
	2013.07	-0.321	-2.103***	-2.144***
		(0.582)	(0.660)	(0.592)
Group 2 (CAR)	2015.11		-0.348**	-0.337**
			(0.163)	(0.148)
	2015.12		-0.525**	-0.500**
			(0.241)	(0.222)
	2016.01		-0.717**	-0.679**
			(0.308)	(0.288)
	2016.02		-0.857**	-0.803**
			(0.375)	(0.354)
	2016.03		-0.788*	-0.707*
			(0.447)	(0.428)
	2016.04		-0.741	-0.634
			(0.526)	(0.508)
	2016.05		-0.330	-0.200
			(0.594)	(0.579)
	2016.06		-0.148	-0.00116
			(0.656)	(0.644)
	2016.07		-0.165	0.000734
			(0.712)	(0.704)
Group 3 (CAR)	2016.08			0.0881
				(0.149)
	2016.09			0.205
				(0.227)
	2016.10			0.372
				(0.296)
	2016.11			0.311
				(0.360)
	2016.12			0.293
				(0.422)
	2017.01			0.209
				(0.474)
	2017.02			0.231
				(0.528)
	2017.03			-0.0938
				(0.579)
	2017.04			-0.324
				(0.630)
	2017.05			0.284
				(0.680)
	2017.06			0.910
				(0.732)

TABLE A1— ESTIMATION RESULTS OF THE EVENT STUDY EQUATION (CONT'D)

(b) Diesel

Variables		Group 1	Group 2	Group 3
Group 3 (CAR)	2017.07			1.638**
				(0.785)
	2017.08			2.290***
				(0.842)
	2017.09			3.371***
				(0.901)
	2017.10			4.547***
				(0.953)
	2017.11			5.620***
				(1.006)
	2017.12			5.918***
				(1.053)
	2018.01			6.137***
				(1.096)
	2018.02			6.238***
				(1.133)
	2018.03			6.477***
				(1.171)
	2018.04			6.705***
				(1.209)
	2018.05			6.855***
				(1.243)
	2018.06			6.892***
				(1.275)
	2018.07			6.928***
				(1.307)
Constant		0.842	-3.695***	-4.006***
		(1.398)	(0.680)	(0.678)
Observations		129	222	297
R-squared		0.870	0.781	0.826
Standard errors in parentheses			*** p<0.01, ** p<0.05, * p<0.1	

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