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# Finding Loopholes in Sanctions: Effects of Sanctions on North Korea's Refined Oil Prices<sup>†</sup>

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*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

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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.<sup>1</sup> 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<sup>2</sup> 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.

<sup>1</sup>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.

<sup>2</sup>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

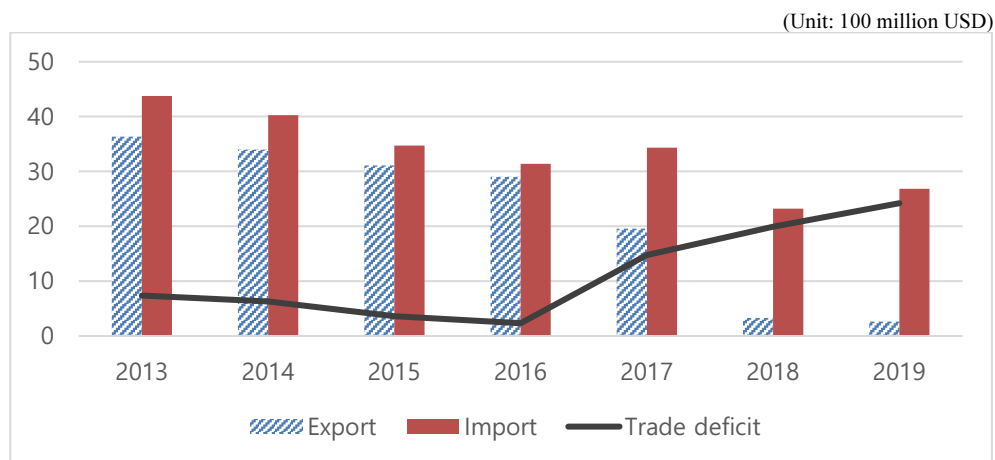


FIGURE 1. NORTH KOREA'S TRADE VOLUME AND BALANCE

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.<sup>3</sup>

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,

<sup>3</sup>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.

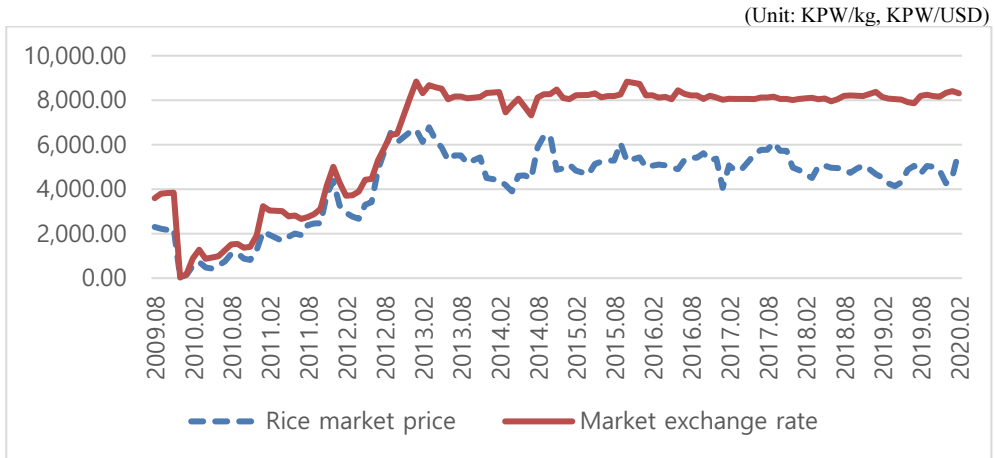


FIGURE 2. RICE MARKET PRICE AND MARKET EXCHANGE RATE IN NORTH KOREA

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<sup>4</sup>

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.”<sup>5</sup> The refined oil data used in this study are monthly price data from September of 2010 to November of 2018.

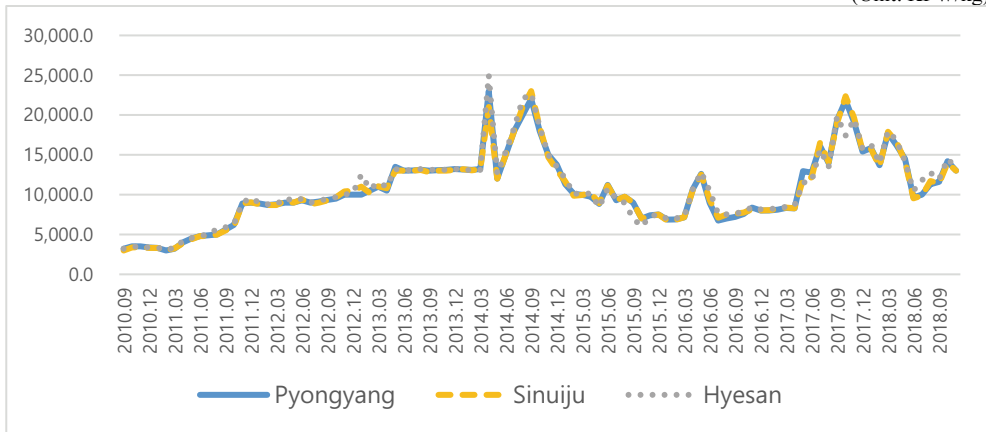
At this point, we examine the price trends of gasoline and diesel traded in North Korean markets. Figure 3 shows the market prices of gasoline and diesel (based on the North Korean won). First, it can be seen that gasoline and diesel prices in Pyongyang, Sinuiju, and Hyesan do not vary significantly 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

<sup>4</sup>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 Korea that announces prices in North Korea, thus enabling us to double-check the figures.

<sup>5</sup><https://www.dailynk.com/english/market-trends>

## [1. Gasoline]

(Unit: KPW/kg)



## [2. Diesel]

(Unit: KPW/kg)

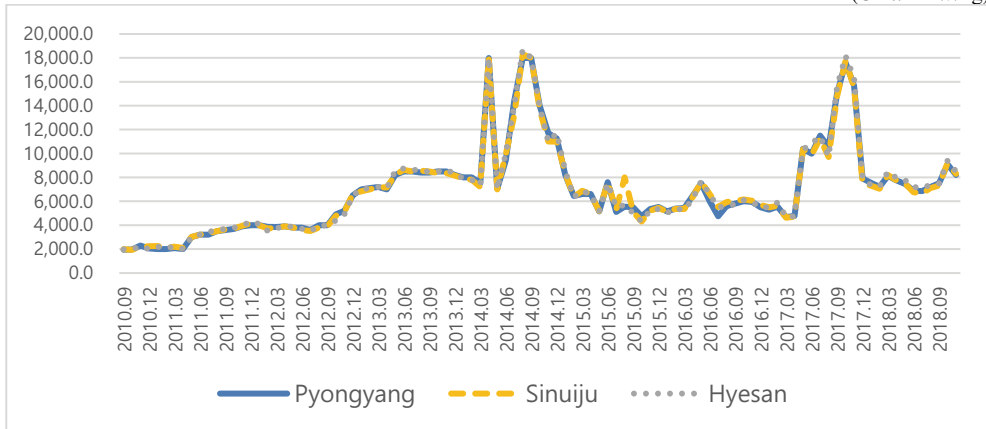


FIGURE 3. NORTH KOREA'S GASOLINE AND DIESEL MARKET PRICES (NORTH KOREAN WON)

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.

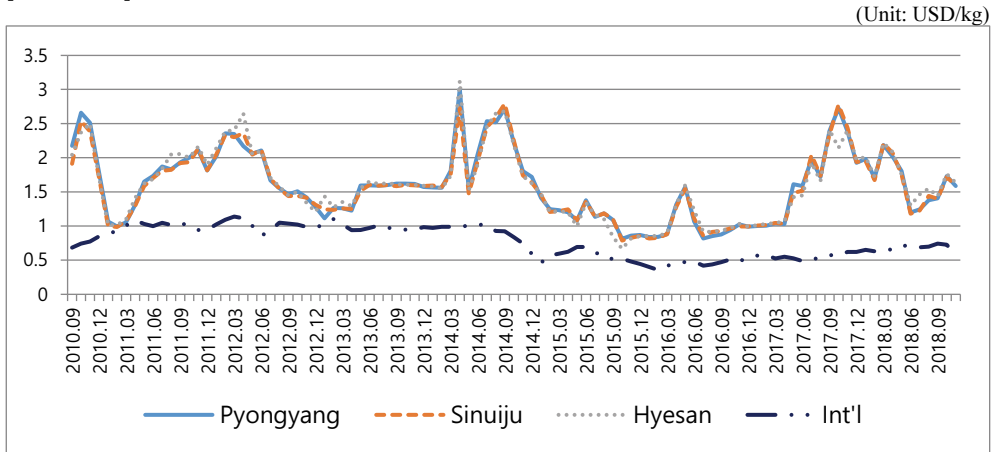
From 2015 to early 2017, there were several price hikes, but lower than the volatile period in 2014. Since mid-2017, prices have soared again to the level of 2014, later entering a downward trend, starting in October 2017. In the second half of 2017, when the UN Security Council resolution on North Korea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



## [2. Diesel]

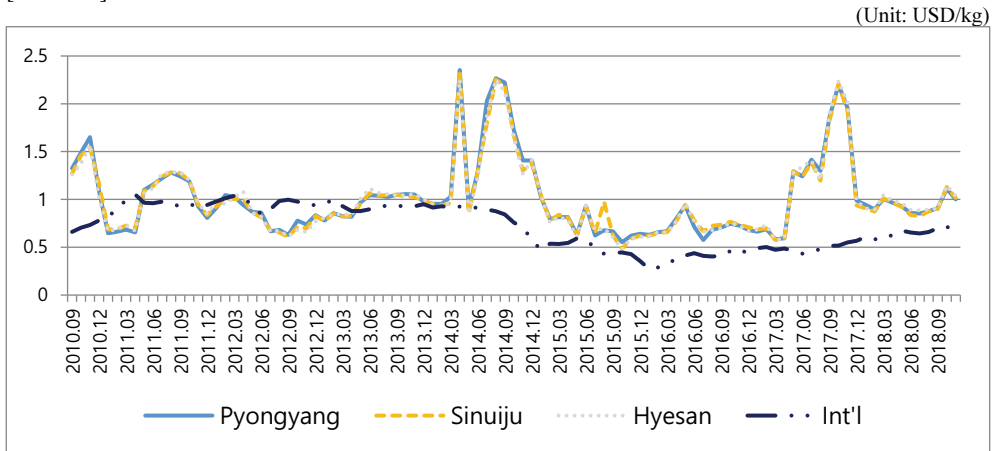


FIGURE 4. NORTH KOREA'S GASOLINE AND DIESEL MARKET PRICES AND INTERNATIONAL PRICES

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.<sup>6</sup>

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,

<sup>6</sup>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.

$$\begin{aligned} y_{i,t} &= X_{i,t}\beta + \alpha_i + CAR_t + e_{i,t} & \text{if } t = 1 \\ y_{i,t} &= X_{i,t}\beta + \alpha_i + CAR_t - CAR_{t-1} + e_{i,t} & \text{if } t > 1 \end{aligned}$$

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.  $\alpha_i$

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  $\alpha_i$ , 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  $\alpha_i$  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

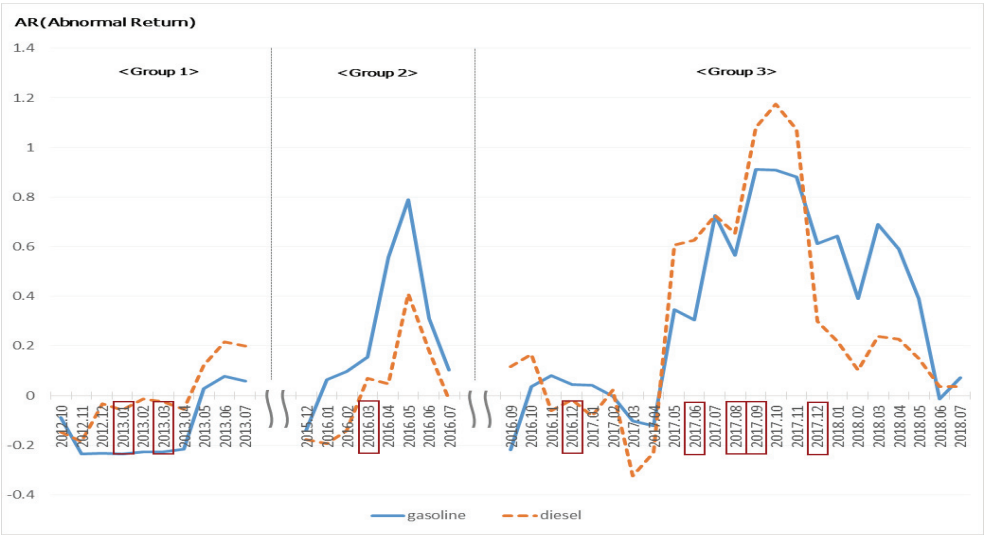


FIGURE 5. IMPACT OF SANCTIONS ON THE PRICES OF REFINED OIL IN THE NORTH KOREAN MARKET

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<sup>7</sup> 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 ( $\approx$  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.

<sup>7</sup>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.<sup>8</sup> 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<sup>9</sup> and the U.S. Mission to the United Nations<sup>10</sup> estimate that the total amount of refined petroleum products introduced by North Korea in 2016 reached 4.5 million barrels (about 600 thousand tons<sup>11</sup>), 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.

<sup>8</sup>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.

<sup>9</sup>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=](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=)).

<sup>10</sup>"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/>).

<sup>11</sup>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.<sup>12</sup> 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<sup>13</sup> is added, the amount of refined petroleum products introduced by North Korea in 2018 would reach between 200 thousand and 450 thousand tons.<sup>14</sup> 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

<sup>12</sup>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.

<sup>13</sup>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>).

<sup>14</sup>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*** (0.117)	0.820*** (0.0955)	0.857*** (0.0911)
Log (Rice price)	0.0951 (0.130)	0.0345 (0.0986)	0.0237 (0.0952)
Log (China export price)	0.855*** (0.193)	0.951*** (0.0639)	0.854*** (0.0712)
Import volume	7.48e-06 (5.94e-06)	1.58e-05*** (3.61e-06)	1.29e-05*** (3.62e-06)
Group 1 (CAR)	2020.09	-0.205* (0.122)	-0.327*** (0.118)
	2020.10	-0.293 (0.186)	-0.477*** (0.174)
	2012.11	-0.528** (0.236)	-0.838*** (0.221)
	2012.12	-0.761*** (0.282)	-1.150*** (0.260)
	2013.01	-0.996*** (0.323)	-1.524*** (0.295)
	2013.02	-1.224*** (0.362)	-1.866*** (0.327)
	2013.03	-1.450*** (0.403)	-2.210*** (0.361)
	2013.04	-1.666*** (0.441)	-2.521*** (0.391)
	2013.05	-1.639*** (0.479)	-2.588*** (0.419)
	2013.06	-1.562*** (0.512)	-2.623*** (0.443)
	2013.07	-1.503*** (0.546)	-2.702*** (0.467)
			-0.318*** (0.112)
			-0.485*** (0.164)
			-0.844*** (0.208)
			-1.180*** (0.245)
			-1.565*** (0.278)
			-1.925*** (0.307)
			-2.284*** (0.339)
			-2.620*** (0.368)
			-2.716*** (0.393)
			-2.775*** (0.416)
			-2.870*** (0.438)

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

## (a) Gasoline

Variables	Group 1	Group 2	Group 3
2015.11		-0.265** (0.116)	-0.321*** (0.113)
2015.12		-0.407** (0.170)	-0.533*** (0.171)
2016.01		-0.343 (0.216)	-0.577*** (0.217)
2016.02		-0.246 (0.266)	-0.584** (0.270)
Group 2 (CAR)	2016.03	-0.0899 (0.317)	-0.524 (0.330)
	2016.04	0.467 (0.369)	-0.0639 (0.393)
	2016.05	1.258*** (0.420)	0.617 (0.450)
	2016.06	1.568*** (0.466)	0.840* (0.505)
	2016.07	1.672*** (0.512)	0.840 (0.554)
	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)
Group 3 (CAR)	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
2017.11			4.357*** (0.775)
2017.12			4.968*** (0.808)
2018.01			5.610*** (0.842)
2018.02			6.000*** (0.869)
Group 3 (CAR) 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*** (1.126)	-4.767*** (0.516)	-4.303*** (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*** (0.123)	1.299*** (0.134)	1.354*** (0.121)
Log (Rice price)	-0.188 (0.128)	-0.325** (0.137)	-0.377*** (0.125)
Log (China export price)	0.0578 (0.253)	0.551*** (0.0824)	0.591*** (0.0869)
Import volume	5.41e-06 (3.83e-06)	1.87e-05*** (4.41e-06)	1.86e-05*** (3.96e-06)
2020.09	-0.340*** (0.126)	-0.510*** (0.164)	-0.498*** (0.147)
2020.10	-0.488** (0.191)	-0.725*** (0.244)	-0.707*** (0.219)
2012.11	-0.673*** (0.244)	-1.036*** (0.310)	-1.018*** (0.279)
Group 1 (CAR) 2012.12	-0.705** (0.292)	-1.221*** (0.369)	-1.206*** (0.332)
2013.01	-0.764** (0.337)	-1.440*** (0.420)	-1.432*** (0.378)
2013.02	-0.779** (0.378)	-1.653*** (0.465)	-1.652*** (0.418)
2013.03	-0.803* (0.425)	-1.881*** (0.511)	-1.883*** (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* (0.469)	-2.172*** (0.551)	-2.182*** (0.495)
	2013.05	-0.737 (0.506)	-2.251*** (0.589)	-2.271*** (0.529)
	2013.06	-0.521 (0.542)	-2.174*** (0.624)	-2.206*** (0.560)
	2013.07	-0.321 (0.582)	-2.103*** (0.660)	-2.144*** (0.592)
	2015.11		-0.348** (0.163)	-0.337** (0.148)
Group 2 (CAR)	2015.12		-0.525** (0.241)	-0.500** (0.222)
	2016.01		-0.717** (0.308)	-0.679** (0.288)
	2016.02		-0.857** (0.375)	-0.803** (0.354)
	2016.03		-0.788* (0.447)	-0.707* (0.428)
	2016.04		-0.741 (0.526)	-0.634 (0.508)
	2016.05		-0.330 (0.594)	-0.200 (0.579)
	2016.06		-0.148 (0.656)	-0.00116 (0.644)
	2016.07		-0.165 (0.712)	0.000734 (0.704)
	2016.08			0.0881 (0.149)
Group 3 (CAR)	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
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)
Group 3 (CAR)	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 (1.398)	-3.695*** (0.680)	-4.006*** (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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# Immigration to Korea: A Fiscal Boon or Burden?<sup>†</sup>

By JINWOOK HUR\*

*This paper intends to examine the extent of the fiscal contribution of immigrants to Korea. According to this analysis, the aim is to derive implications pertaining to the direction of Korea's immigration policy as a response to fiscal problems caused by population aging. For this purpose, a macroeconomic model is designed to measure the lifetime net fiscal contribution of immigrants in Korea by visa type, age, and other characteristics. According to this analysis, the sum of the lifetime fiscal contribution for all immigrants in Korea is negative. This implies that immigration policy reforms that increase the inflow size while maintaining the current structure of the foreign population characteristics can rather worsen Korea's fiscal problems. This finding suggests that immigration policy reform may exacerbate Korea's fiscal soundness if it simply targets the maintenance of the numerical balance of the demographic structure.*

Key Word: Immigration, Fiscal Sustainability, Population Aging  
JEL Code: E60, H50, J61

## I. Introduction

It is well known that Korea is one of the most rapidly aging countries in the world. The working-age population (15–64) has been in decline since 2017, and the overall population is expected to start declining in 2029 (Statistics Korea, 2019). Korea is still a younger country than most developed economies, such as those in Western Europe and Japan, but the speed of aging is expected to be far higher than in those countries. With this rapid population aging, the major problems already experienced by developed economies, such as problems with fiscal sustainability, can also occur in Korea, but more severely.

As these population imbalances and related problems have emerged as a major issue during the establishment of policy directions in Korea, various alternatives are

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being discussed. One of these alternatives is a change to Korea's immigration policy so that Korea will allow more immigrants. While allowing immigrants into Korea has thus far mainly been thought of as a means by which to meet labor demands, the recent idea of an expansionary immigration policy considers immigration as a tool to mitigate the speed of population aging. In particular, mitigating problems such as low growth and the fiscal imbalance caused by the decline of the working-age population by allowing working-age immigrants who can engage in economic activities in Korea has been argued.

Indeed, it is not a new phenomenon from a global perspective that the expansion of immigration policy is mentioned as an alternative to aging. Some European countries, such as Germany and Sweden, which experienced slowing population growth caused by aging prior to Korea, have implemented active population inflow policies with the aim of securing labor and improving fiscal soundness. Even in other advanced economies, it is reported that countries with severe population aging tend to have a high proportion of immigrants to the native population.<sup>1</sup> Therefore, for the U.S. and the major European countries, the socio-economic effects of an influx of immigrants have been studied from various perspectives, as the movement of populations among those countries has been more active for more time compared to population movements in Korea. On the other hand, in Korea, it has not been as long since such discussions actively began. Although the number of foreigners residing in Korea is increasing rapidly, statistical data related to them have not been sufficiently accumulated quantitatively or qualitatively; accordingly, research to derive policy implications through rigorous empirical analyses remains as a future task.

However, despite the limited availability of data, analyzing the economic effects of immigration inflows is essential when setting immigration policies to respond to population aging. The main problem of aging is not simply stagnant or declining populations but rather a problem arising from the decrease in the relative size of the working-age population relative to the dependent population due to aging. In other words, a major policy consideration is whether various fiscal systems such as welfare systems can be sustained even during a population imbalance. Therefore, predicting how immigration policies can solve the problem of a population imbalance from an economic perspective using available statistics must be done prior to actual policy making activities. In this sense, it is an important task to predict the fiscal impact of immigrants using quantitative economic models.

For this purpose, this study aims to examine the main characteristics of foreigners residing in Korea based on available statistical data and then to quantitatively measure their impact on the government's fiscal soundness in Korea. Specifically, the main content of this study involves a measurement of how much immigrants will contribute through tax and fee payments relative to the amount of government expenditure caused by them, depending on their main characteristics, specifically their visa type, gender, and age. In particular, by estimating how the fiscal contribution of immigrants differs according to the visa type held, this study attempts to derive implications for current foreigner policies in Korea, especially visa issuance policies.

This study is related to the literature on the fiscal impact of immigrants to the host

<sup>1</sup>Lee *et al.* (2015).

country. First, in a study of the U.S. economy, Auerbach and Oreopoulos (1999) estimated the fiscal effect of an influx of immigrants on the U.S. economy, arguing that if immigrants are strictly limited to young and highly skilled workers, the fiscal burden can be partially mitigated, whereas the overall fiscal effect appears to be insignificant. Lee and Miller (2000) also draw similar conclusions using models that more realistically reflect the population sector. On the other hand, Storesletten (2000) analyzes the fiscal effect of an immigration inflow using a general equilibrium model reflecting the productivity effect on the supply side due to the immigration inflow. In this analysis, he argues that allowing 1.6 million highly skilled immigrants aged 40-44 into the U.S. economy every year can maintain the fiscal sustainability of the U.S. government even without tax reforms. Among studies focusing on European cases, Storesletten (2003) examines the fiscal impact of immigrants entering Sweden using Swedish data. In that case, it was found that immigrants aged approximately 20 to 35 make a positive contribution to the fiscal soundness of Sweden, whereas immigrants of other ages have a negative impact considering that government expenditures related to this group exceeds their lifetime taxes and fees. In other words, he claims that the ages of immigrants have a considerable influence on their degree of fiscal contribution. Schou (2006) presents the results of an analysis of the CGE model using Danish data, showing that the average immigrant imposes a greater fiscal burden compared to their fiscal contribution. Rowthorn (2008) conducts an empirical analysis of immigrants in major European countries and shows that the net contribution of immigrants to the host country's fiscal status as a whole is positive but negligibly small. On the one hand, Imrohoroglu *et al.* (2017) argues that increasing short-term foreign workers (guest workers) is a reasonable policy alternative to Japan's rapidly aging and declining working-age population using a general equilibrium model analysis. In their study, they argue that Japan's fiscal problem can be partly solved by allowing more guest workers even if all of the immigrant workers are low-skilled workers.

With regard to studies of the Korean economy, few explicitly analyze the fiscal contributions of immigrants. One of these with theme similar to this is that of Chun (2012), which focuses on how the influx of immigration affects overall productivity in Korea. He shows that the inflow of immigrants can increase the per-capita GDP if their productivity is high enough and public expenditures on them are not excessively large. Lee *et al.* (2009) analyzes the effect of an influx of immigrants on the population structure of Korea, concluding that if multicultural families increase, their high fertility rates can substantially alleviate the population imbalance and decline in the working-age population otherwise occurring due to aging in Korea.

This study aims to estimate the fiscal impact of immigrants entering Korea according to visa type, gender, and age, referring to the earlier studies mentioned above. The model for the analysis basically stems from the partial equilibrium model used in existing articles but is modified and extended to reflect the actual Korean economy. For the sectors related to household consumption and the labor market in the model, the method of Storesletten (2003) is applied, in which consumption, savings, and labor input are determined in the form of behavioral equations instead of solutions to the optimization problem. However, his model is modified and extended for the government sector and the immigration policy sector so that it can reflect the reality of Korea to the greatest extent possible. In particular, the national

pension, government consumption and transfers are modeled to better suit the Korean system.

Moreover, one of the expected contributions of this study to the literature is that the model actually reflects a visa issuance policy suitable for the reality of Korea. In many existing partial equilibrium estimation models, it is often assumed that all immigrants stay without leaving the host country for their lifetime once they enter, while the model used in this study distinguishes major visa types and derives a solution using not only age and gender but also the immigrants' visa types. Therefore, the method of this study is specialized in deriving implications for immigration policy – i.e., the visa type to be issued.

The rest of this paper proceeds as follows. The immigration policy and visa types existing in Korea are introduced in Section II. The model setup is demonstrated in Section III, and the calibration strategy is explained in Section IV. After describing the results of the analysis in Section V, Section VI concludes the paper.

## II. Immigration Policy and Major Visa Types of Korea

Before explaining the model analysis, this section briefly introduces Korea's major visa types. First, the paper discusses how visa types are classified. Based on this, one of the main data sources used in this study, the *Survey on Immigrant's Living Conditions and Labour* by Statistics Korea, is discussed.

The main purpose of this study is firstly to estimate the fiscal contribution of foreigners who stay in Korea for a reasonably long time. Accordingly, foreigners entering Korea with a visa for less than one year are excluded from the analysis, and the subject of the analysis is limited to those with a visa that allows a stay of one year or more. Those foreigners (with a visa for one year or more) are defined as "immigrants" in this study.<sup>2</sup> There can be several ways to classify immigrants, but in this paper, the methods of Lee and Nho (2013)<sup>3</sup> are applied. Table 1 classifies the types of immigrants into those present for short-term work purposes, long-term work purposes, family purposes, and long-term residence purposes.

Each category of Table 1 is described as follows. First, the short-term work purpose type consists of visas such as those for students (D-2, D-4-1, and D-4-7), non-professional employment (E-9), and work visits (H-2). The non-professional (E-9) types are for foreigners entering Korea under the employment permit system, and the government decides on the number of these according to the industry based on the demands of companies that want to hire foreign workers. Regarding work visitors (H-2), the government also determines the number of visas issued from compatriots in China and countries of the former Soviet Union. In other words, the numbers of both E-9 and H-2 visas issued are controlled by the Korean government. They are termed "short-term" in the sense that their period of stay is limited, and

<sup>2</sup>The Statistics Division of the United Nations defines "international long-term immigrants" as those who live in a country other than their main residence for more than 12 months, and "international short-term immigrants" as those staying for 3~12 months. This paper refers to foreigners residing in Korea who plan to remain for one year or more as "immigrants."

<sup>3</sup>Lee and Nho (2013) classify Korean visa types in accordance with OECD standards. Lee *et al.* (2014) analyzes the statuses of foreigners' entering and leaving according to this classification.

TABLE 1—CATEGORIZATION OF IMMIGRANTS

Purposes	Years of Stay	Visas in Each Category
Short-term Work Purpose	1~5 years	Non-professional Employment (E-9), Work Visit (H-2)
Long-term Work Purpose	5 years +	Professorship (E-1), Foreign Language Instructor (E-2), Research (E-3), Technology Transfer (E-4), Professional Employment (E-5), Arts and Performances (E-6), Special Occupations (E-7)
Family Purpose	5 years +	Family Visitation (F-1), Residency (F-2), Dependent Family (F-3), Marriage Migrant (F-6)
Long-term Residence Purpose	5 years +	Overseas Koreans (F-4), Permanent Residency (F-5)

Source: Lee and Nho (2013) and Lee *et al.* (2014) modified by the author.

once the period of stay is over, they must go through a procedure for re-qualification from the beginning.<sup>4</sup>

In contrast, regarding the other types (long-term work purposes, family purposes, and long-term residence purposes), extension of the visa is free or only slightly limited. While the aforementioned non-professional employment or work visit adopt a limited length of stay to prevent settlement, the visas in the other categories are relatively flexible in allowing an extension. The long-term work purpose visas are mainly called “professional staff” (E-1~E-7 visas), as they consist of visas for cases such as professorships, research, and conversational instruction. The family purpose type consists of residential (F-2), family visitation (F-1), and marriage migrant (F-2-1, F-6) visas.

Table 2 shows the amounts of immigrants staying by visa type as of the end of 2016. It can be observed that non-professionals, work visitors, overseas Koreans, and marriage migrants account for a high proportion, whereas the number of professional staff visas is relatively small.

The most important data source used in this study to examine how the fiscal contribution of immigrants differs in terms of visa type, gender, and age is the “Survey on Immigrant’s Living Conditions and Labour Force.” This survey extracts samples from all registered foreigners in Korea and categorizes them according to eight visa types – non-professional employment (E-9), work visits (H-2), professional staff (E-1~E-7), students (D-2, D-4-1, D-4-7), overseas Koreans (F-4), permanent residents (F-5), marriage migrants (F-6, F-2-1), and others (See Figure 1). The survey includes gender, age, period of stay in Korea, average monthly income, labor force participation, employment, and other measures. Therefore, the actual model analysis is conducted according to the classification of visa type in the “Survey on Immigrant’s Living Conditions and Labour Force,” considering data availability. Student visas (D-2, D-4-1, and D-4-7) are excluded from this study because students do not generally work and thus do not fit the purpose of this study. Regarding this survey data, it is not possible to know which visas comprise the “Other” status, but compared to the number of foreigners staying by visa type

<sup>4</sup>For both the non-professional employment (E-9) and work visit (H-2) types, the period of stay is limited to 3 years, but one extension is possible for one year and ten months. In other words, the allowed stay duration is practically four years and ten months. After this period, one must go through the process of a qualification review from the beginning for re-qualification.

TABLE 2—SCALE OF IMMIGRANTS BY PURPOSE OF STAY AND VISA TYPE (2016)

Purpose of Stay	Visa	Number of Immigrants	Ratio to the Whole Immigrants with 1 year+ Stay (%)	Ratio to the Whole Foreigners (%)
Short-term Work Purpose	Non-Professional (E-9)	279,187	18.81	13.62
	Work Visit (H-2)	254,950	17.18	12.44
Long-term Work Purpose (Professional Staff)	Professorship (E-1)	2,511	0.17	0.12
	Foreign Language Instructor (E-2)	15,450	1.04	0.75
	Research (E-3)	3,174	0.21	0.15
	Technology Transfer (E-4)	187	0.01	0.01
	Professional Employment (E-5)	618	0.04	0.03
	Arts and Performances (E-6)	4,302	0.29	0.21
	Special Occupation (E-7)	21,498	1.45	1.05
Family Purpose	Family Visitation (F-1)	103,826	6.99	5.07
	Residency (F-2)	36,179	2.44	1.77
	Dependent Family (F-3)	22,828	1.54	1.11
	Marriage Migrant (F-6)	152,231	10.26	7.43
Long-term Residence Purpose	Overseas Korean (F-4)	372,533	25.10	18.18
	Permanent Residency (F-5)	102,840	6.93	5.02

Note: The sum of ratios to the immigrants with 1 year+ stay is not 100% since the table discards students and marriage naturalization. The total number of immigrants with 1 year+ stay equals 1,484,315, and the number of total foreigners equals 2,049,441.

Source: Ministry of Justice, “Korean Immigration Service Statistics,” 2016.

## V 체류에 관한 사항

### 29 현재 체류자격은 무엇입니까?

- ☐ 1 E-9(비전문취업)      ☐ 4 D-2, D-4-1, D-4-7(유학생)      ☐ 7 F-6, F-2-1(결혼이민)  
☐ 2 H-2(방문취업)      ☐ 5 F-4(제외동포)      ☐ 8 기타(      )  
☐ 3 E-1~E-7(전문인력)      ☐ 6 F-5(영주, F-5-2(      ))

※ 영주(F-5) 중 “국민의 배우자”(F-5-2)는 괄호 안에 √표시

예시 ☒ F-5 (영주, F-5-2 (√))

FIGURE 1. QUESTIONNAIRE OF THE SURVEY – VISA TYPE

provided by the Ministry of Justice, approximately 72% of foreigners who responded with “Other” are likely to have family-related visas.

## III. Model

The major goal of the model is to derive fiscal implications of the immigration influx by computing immigrants’ fiscal contributions and fiscal costs. A partial equilibrium model is used for the model analysis. Although a partial equilibrium

model does not consider behavioral changes of agents in the markets, it more readily reflects the heterogeneity of agents and maps complex fiscal institution in the real world into the model. Therefore, this study relies on the partial equilibrium setting, in which the only equilibrium condition is the government's long-run budget constraint.

Essentially, the details of the model are similar to those in Storesletten (2003), but the model of this paper better reflects Korea's reality. For instance, the model considers return migration of guest workers, while Storesletten (2003) assumes that all immigrants stay in the host country for life.

The model has dynamic overlapping generation properties. Total population is divided into natives and different types of immigrants, and they earn income by supplying labor. A certain portion of the income is taxed, and each agent then decides how much to consume and save. The government spends tax revenue on various types of government consumption, transfers, pension payments, and other purposes. The details of the model are described below.

### A. Demographic Structure

Total population consists of natives and the immigrant populations holding seven different types of visas. Each person has a gender (either male or female) and age (from 0 to 99). A newborn child is assumed to be zero years old and can live only up to 99 years old. In the model, one period corresponds to one year; therefore, each agent can survive for up to 100 periods.

Agents are distinguished by only five variables – age, gender, labor market participation, visa type, and age at the time of immigration. It is assumed that two agents are perfectly identical if those five types are also identical. For brevity, a five-dimensional type vector  $(i, s)$  is used, in which  $i$  stands for age, and  $s \equiv (s_1, s_2, s_3, s_4)$  for (gender, labor market participation, visa type, age at the time of immigration), respectively. The range of values that each subtype can have is shown in Table 3. Theoretically, the number of types can be as high as  $100 \times 2 \times 2 \times 8 \times 100 = 320,000$ .

First, we discuss assumptions pertaining to the duration of stays for foreigners. In actuality, E-9 (the non-professionals) and H-2 (work visitors) holders are allowed to stay in Korea for up to four years and ten months. In this study, it is assumed that all H-2 and E-9 holders (if they do not die before their visa expires) return to their home country after exactly five years. In other words, the possibility of return migration to the home country is excluded before five years. On the other hand, immigrants with other types of visas (professional staff, marriage migrants, overseas Koreans, permanent residents, and others) are assumed to stay in Korea for their lifetime and never to return to their home countries.

Next, we discuss assumptions about fertility for each type. In reality, it is expected that visa holders for five years or less (such as H-2 and E-9 holders) have very low fertility rates in Korea. In the model, for simplicity it is assumed that the foreigners with these two types of visas do not give birth at all in Korea, and only foreigners with other types of visas (professional staff, marriage migrants, overseas Koreans, permanent resident, and others) are assumed able to give birth in Korea. Additionally,

TABLE 3—TYPES OF THE AGENTS IN THE MODEL

Types	Meaning	Number of Cases	Note
$i$	Age	100	an integer for 0~99
$s_1$	Gender	2	{male, female}
$s_2$	Labor Market Participation	2	{participants, non-participants}
$s_3$	Visa Type	8	{native, non-professional, work visit, professional, marriage migrant, overseas Korean, permanent resident, other}
$s_4$	Age at the Time of Immigration	100	An Integer for 0~99

TABLE 4—ASSUMPTIONS ON FERTILITY AND DURATION OF STAY IN THE MODEL ECONOMY

Visa Types	Able to Give Birth in Korea	Duration of Stay in Korea
Native	O	0 Years Old to Death
Non-professional Work Visit	X	5 Years after Entrance, or Death (Death Can Come Earlier than 5 Years)
Professional Marriage Migrant Overseas Korean Permanent Resident Other	O	Entrance to Death

every child born in Korea is assumed to be a native Korean, even if any of her parents is a foreigner.

Finally, it is assumed that all agents of a certain type have an identical stream of survival rate by age. The unconditional probability that a type  $s$  agent survives at age  $i$  is denoted by  $\Pi_{i,s}$ . Therefore,  $\Pi_{0,s} = 1$  for all  $s$ , and the conditional probability that an agent alive at age  $i$  is alive at age  $i + j$  equals  $\Pi_{i+j,s} / \Pi_{i,s}$ .

### B. Labor Market

The labor market is drastically simplified in order for the model to concentrate on fiscal implications. First, those 19~64 years of age are considered to be of working age. Agents under 19 or over 65 years old are assumed not to work at all. The working-age population consists of labor force participants and non-labor force participants, and the labor force participants are either employed or unemployed. For the sake of simplicity, it is assumed that all agents are divided into labor force or non-labor force participants with a certain probability at the age of 20 and that this status is maintained for their lifetimes thereafter. Moreover, in determination of those employed or unemployed, it is assumed that a predetermined unemployment rate  $u_{i,s}$  exists such that all labor force participants of type  $(i, s)$  are employed for  $1 - u_{i,s}$  of a period and are unemployed for the remaining  $u_{i,s}$  of the period. This simplification intends to resolve the complexity of the computation caused by heterogeneity of the work status within the same type.



The pre-tax wage of each type of labor force participant depends on the type-specific labor productivity and the duration of employment described above. This is expressed as follows:

$$(\text{Labor income of a type } (i, s) \text{ at period } t) = W_t \cdot e_{i,s} \cdot (1 - u_{i,s})$$

Here,  $W_t$  refers to the wage per efficiency unit of labor, which is identical for workers of all types, and  $e_{i,s}$  is a parameter representing the productivity of each type. A worker can earn more labor income by working for the same time if he has a higher  $e_{i,s}$ , implying that there is a wage gap caused by differences in productivity among workers of different types. Regarding non-labor force participants,  $e_{i,s} = 0$  is assumed; that is, no labor income is earned. Moreover,  $W_t$  grows for every period at a rate of  $z$ . In other words, the wage per efficiency unit of labor in period  $t$  is represented by  $W_t = (1 + z)^t W_0$ . This model setup intends to exclude supply-side factors in the usual general equilibrium models by assuming that labor productivity is homogeneous among the agents of the same type. Also, it does not take into account the potential effect on wages or unemployment that the influx of immigrants may cause. In fact, there has long been debate among economists on whether an influx of immigrants can increase the unemployment rate or decrease the wages of existing native workers, but it appears that recent empirical works tend to find no significant effect.<sup>5</sup> Therefore, the assumption pertaining to the labor market above may not be an oversimplification.

### C. Government

The government spends its budget on government consumption, transfers, health insurance benefits, and national pension benefits. The government finances its expenditures by levying taxes.

#### Taxation

Taxation is assumed to have a simple form. The tax system consists of consumption taxes and income taxes (including social insurance contributions). Each of these taxes is considered a proportional tax with a single tax rate. All agents pay  $\tau_c$  of their own consumption and  $\tau_l$  of their own income.

This simplified tax system considering only the two average tax rates in this model is used because it is necessary to estimate the taxpayer's income distribution in order meaningfully to reflect the progressive tax system that most closely approximates

<sup>5</sup>Peri (2014) surveys 270 analyses from 27 of the latest papers that empirically analyze the effects of an influx of immigrants on the wage levels of native workers for different countries, regions, and methods, finding that more than 75% of the studies conclude that the elasticity of the immigration influx is between -0.2 and 0.2, i.e., close to zero. In addition, the remaining 25% of the studies conclude that the effect of immigrants on the wages of the natives is positive. In particular, most studies of the short-term effects of immigration find that the effects of immigration are close to zero, whereas studies of long-term effects find that the estimated effects of immigration are positive.

reality. However, there is not a sufficiently good data source by which to measure the income distribution of immigrants to Korea. Although the average monthly salary of foreign workers is surveyed by the *Survey on Immigrants Living Conditions and Labour Force* of Statistics Korea, it is difficult to maintain the significance of the results, as the sample size is very small if classified according to visa type or age. Moreover, the monthly salary data are represented only in a wide range, making it difficult meaningfully to estimate the income distribution of immigrants.<sup>6</sup> Therefore, in this study, only a simple tax system with a single tax rate for both income and consumption is assumed.

## Government Consumption

Government consumption consists of a variety of subcategories, some of which are used intensively for specific types of agents (e.g., education, health), while others are utilized on the population as a whole (e.g., defense, SOC). Considering these points, in the model it is assumed that the amount of government consumption per agent can differ for each type. For the initial period ( $t = 0$ ), the amount of government consumption per agent with type  $(i, s)$  is denoted as  $g_{i,s}$ , and the measure of population with type  $(i, s)$  at period  $t$  is denoted as  $\mu_{i,s,t}$ . It is also assumed that the per-capita government consumption increases at a rate identical to that of the average wage mentioned above. As a result, the total government consumption for period  $t$  is expressed as follows:

$$G_t = (1 + z)^t \sum_{i,s} g_{i,s} \mu_{i,s,t}$$

## Transfers

Transfer payments are divided into welfare expenditures ( $b_{i,s}$ ) and work-related expenditures, and work-related expenditures are again divided into unemployment benefits ( $ub_{i,s}$ ) and industrial accident compensation ( $ia_{i,s}$ ). Welfare expenditure is divided into expenditures for specific types and spending for the entire economy in a manner similar to the above-mentioned government consumption. All components of the transfer payments ( $b_{i,s}$ ,  $ub_{i,s}$ ,  $ia_{i,s}$ ) are assumed to grow at a rate of  $z$  every period; this rate is identical to the growth rate of wages.

It is assumed that welfare expenditures are transferred to the beneficiary at a fixed amount, while work-related expenditures are paid in proportion to the productivity of the beneficiary. Unemployment benefits ( $b_{i,s}$ ) are also assumed to be distributed to labor force participants during unemployment periods, and industrial accident compensation ( $ia_{i,s}$ ) is distributed to the labor force participants during employment periods. As a result, welfare expenditures, unemployment benefits, and industrial

<sup>6</sup>The total amount of monthly income of foreigners surveyed is listed in only four categories: “less than 1 million won,” “1 million to 2 million won,” “2 million to 3 million won,” and “more than 3 million won.”

accident compensation per capita for each type are summarized below.

$$(\text{Welfare expenditure per capita in type } i, s) = b_{i,s}$$

$$(\text{Unemployment benefit per capita in type } i, s) = u_{i,s} e_{i,s} u b_{i,s}$$

$$(\text{Industrial accident comp. per capita in type } i, s) = (1 - u_{i,s}) e_{i,s} i a_{i,s}$$

### Health Insurance and National Pension

National health insurance is assumed to be subscribed to by all agents, including immigrants, while the national pension is subscribed to only by labor force participants. The volume of health insurance benefits ( $hc_{i,s}$ ) differs according to the type of beneficiary depending here on their age, gender, visa status, and other factors and does not rely on the timing of work entrance or work status. The national pension benefit ( $pen_{i,s}$ ) is basically paid to retirees aged 65 years or older in the model and depends on the recipient's labor income while she was working when young (termed the "B-value") and the average total income of all subscribers ("A-value") such that it mimics Korea's national pension system in reality. It is assumed that these two benefits ( $hc_{i,s}$ ,  $pen_{i,s}$ ) also grow at a rate of  $z$ , as does the wage rate. Details of the calculation method are described in the next section on the calibration of the model.

#### D. Private Consumption

All agents, including natives and immigrants, spend all of their disposable income on consumption during their lifetimes. Newborn children begin their life without any initial assets. With regard to immigrants, the possibility of immigration with some assets is considered, but it is assumed that the income immigrants earned before their migration is exactly equal to the income that would have been obtained if they had done business in the host country.

Assuming a constant relative risk aversion, a constant interest rate and a constant growth rate, the propensity to consume for each period is determined only by age but not by the timing of consumption. Therefore, the propensity to consume corresponding to each type can be denoted as  $\{\xi_{i,s}\}_{i=0}^{99}$  without the time subscript. The consumption function of the initial period ( $t = 0$ ) can then be expressed as the portion corresponding to the propensity to consume among the present value of lifetime income, as follows:

$$c_{i,s,0} = \frac{\xi_{i,s}}{1 + \tau_c} \cdot \sum_{j=0}^{99} \Pi_{j,s} R^{-j} (1+z)^j \cdot [\{(1-\tau_1)W_0 + i a_{j,s}\} (1-u_{j,s}) e_{j,s} + u b_{j,s} u_{j,s} e_{i,s} + \varphi_{j,s}]$$

The expression between the square brackets on the second line represents the sum of all types of income by the type ( $i, s$ ) of agent. The first term in the brackets

indicates the sum of wages and industrial accident compensation and the second term represents unemployment benefits. In the last term,  $\varphi_{i,s} \equiv b_{i,s} + hc_{i,s} + pen_{i,s}$  represents the agent's income, determined to be unrelated to the agent's productivity, such as welfare expenditures, health insurance, and national pension benefits.  $R$  is a time-invariant gross interest rate and  $\Pi_{i,s}$  represents the unconditional probability of survival for each type.

In the above consumption function, because  $W$ ,  $ia_{i,s}$ ,  $ub_{i,s}$ , and  $\varphi_{i,s}$  grow at the same rate  $z$ , consumption also increases precisely at the same rate every period. Thus, per-capita consumption by type can be expressed by the following formula.

$$c_{i,s,t} = (1 + z)c_{i,s,t-1}$$

### E. Equilibrium Condition

As shown thus far, this model has a simplified structure in which the wage rate is determined exogenously and consumption is determined by the consumption function of the households instead of explicitly considering the optimization problem of the households. Therefore, the wage rate and parameters of the consumption function must be given from outside the model. The only equilibrium condition in this model, therefore, is the inter-temporal government budget constraint (IGBC, henceforth). The IGBC means that the government's initial debt size must equal the sum of the present value of the future primary fiscal balance so that the government's debt satisfies the 'No Ponzi Game Condition'. If this equation is not satisfied, it means that the government debt level is not sustainable given the current tax revenue and government expenditures. The IGBC of this model can be represented by the following equation.

$$(1) \quad D_0 = \sum_{t=0}^{\infty} R^{-t} (REV_t - G_t - T_t - HC_t - PEN_t)$$

Here,  $D_0$  represents government debt in the initial period,  $REV_t$  is the total tax revenue at time  $t$ ,  $G_t$  denotes government consumption at  $t$ ,  $HC_t$  is the total health insurance benefit, and  $PEN_t$  is the national pension benefit. Therefore,  $(REV_t - G_t - T_t - HC_t - PEN_t)$  is equal to the primary balance of the government.

## IV. Calibration

Most of the parameters are sourced from data outside of the model, and only a few parameters are determined inside the model by the fiscal equilibrium condition (IGBC). This section describes the calibration method used for the key parameters and distribution. Basically, most of the parametrization steps are conducted to match the initial economy ( $t = 0$ ) of the model to the actual figures for 2015.

## A. Demographic Structure and Dynamics

### Fertility and Mortality Rates

Fertility and mortality rates are assumed to remain at the 2015 level for all periods in this analysis. The fertility rate of native women by age is calculated using data from the ‘Vital Statistics’ and ‘Population Census’ databases of Statistics Korea. Regarding the fertility rate of foreign women in Korea, however, there is not much reliable data. For example, if the mother of a newborn child born in 2015 is a foreigner, one can find the mother’s age and nationality but cannot find her visa status. Thus, it is difficult to estimate the fertility rate by age and visa status.

Therefore, assumptions must be applied to calibrate fertility by visa type in this model. First, it is assumed that non-permanent immigrants (E-9 and H-2 holders) do not give birth in the host country at all. Considering they can stay with their visa only up to five years, this may not be a strong assumption. Secondly, the fertility of marriage migrant visa holders is estimated according to the fertility of female immigrants (with all visa types) from selected countries<sup>7</sup> with high ratios of marriage migrants. Thirdly, the fertility of those with other types of visas (professional staff, overseas Koreans, permanent residence, and others) is assumed equal to that of native women. As mentioned above, all newborns are considered to be native Koreans regardless of their parents’ nationalities.

The gender ratio of newborns is fixed at 105:100 assuming that the actual birth rate in the “Vital Statistics” database of Statistics Korea in 2015 will be maintained in the future. This ratio is assumed to be independent of the mother’s age, labor market participation, and visa status.

The age-mortality rate profile is calculated according to the unconditional probability of death for each age using the “Life Tables by Province” data from Statistics Korea. It is also assumed that there is no difference between foreigners and Koreans in terms of mortality.

TABLE 5— CALIBRATION OF PARAMETERS ON FERTILITY AND MORTALITY

Parameter	Visa Type	Method
Fertility	Native	“Population Census”, 2015 by Statistics Korea
	Marriage Migrant	Fertility of females from major source countries of marriage migrants. Data sources are “Vital Statistics” of Statistics Korea and “Korean Immigration Service Statistics” of Ministry of Justice of Korea
	Non-professional and Work Visit	Assume that they do not give birth in Korea
	Immigrants other than above	Assume the identical fertility with the native
Mortality	all	Unconditional mortality rate is computed using “Life Tables by Province” of Statistics Korea. (Mortality rate of immigrants is assumed to be equal to that of the native.)

<sup>7</sup>The selected countries are those with 45% or more marriage migrants (F-6) out of all immigrants and where the number of marriage migrants exceeds 100. Those countries are Laos, Vietnam, and the Philippines. In other words, the fertility rate of all female immigrants from those three countries is used as a proxy for the fertility of all female F-6 holders. The estimated TFR is 2.63, lower than the estimate by Lee *et al.* (2009).

## Population Distribution and Immigration Policy

The population of natives by gender and age is constructed using data from the “Population Census” of 2015. The distribution of immigrants by gender and age is calculated using the 2015 source data entitled “Survey on Immigrant’s Living Conditions and Labour Force” by Statistics Korea.

Regarding the immigration policy – the number of immigrants by visa type, gender, and age – it is assumed that the immigration policy of 2015 will be maintained in the future. In other words, new migrants in the period after 2015 will have an identical distribution in 2015 with regard to visa type, gender, and age. First, using data from the “Survey on Immigrant’s Living Conditions and Labour Force” of 2015, the number of immigrants who reported that their length of stay is less than a year is calculated according to visa type, gender, and age. Then, from 2016, it is assumed that the amount and distribution of immigrants that enter each year remain the same. The key features of new immigrants in the model economy are shown in Table 6.

TABLE 6— CALIBRATION IMMIGRATION POLICY: ANNUAL NEW ENTRANCES BY VISA TYPE

Visa Type	Number of Entrants	Average Age	Average Gender Ratio (M : F)
Non-professional	35,470	27.5	1,180 : 100
Work Visit	34,138	44.9	207 : 100
Professional	6,933	28.6	117 : 100
Marriage Migrant	3,963	32.6	13 : 100
Overseas Korean	19,780	54.2	123 : 100
Permanent Residence	564	55.2	68 : 100
Others	32,554	40.6	96 : 100

Source: Calculated using Statistics Korea, “Survey on Immigrant’s Living Conditions and Labour Force.”

## Return Migration

With regard to the non-professional employment (E-9) and work visit (H-2) types, it is considered that their upper limits for stays are fixed at four years and ten months in both cases. However, instead of granting a ceiling within the model, all E-9 and H-2 holders are assumed to return to their home country after living in Korea for exactly five years. Regarding the residences of the remaining types of visas, it is assumed that they all remain in Korea for their lifetimes.

### B. Economic Activity and Labor Market

The working-age population ranges from 19 to 64 years old, and those in the population aged outside this range are assumed to have zero labor productivity. The efficiency unit wage rate ( $W_0$ ) of the initial economy is set such that the total annual income of the working-age population equals 1,568 trillion won, which equals Korea’s growth national income (GNI) of 2015.<sup>8</sup> The growth rate of  $W_t$  (denoted

<sup>8</sup>In other words, income from factors other than labor is combined with labor income. Because the amount of

by  $z$  in the model) is assumed to be 3% annually, and the gross interest rate ( $R$ ) is assumed to be 1.04, i.e., net interest rate of 4% per year.

The implications of parametrizing  $z$  and  $R$  are as follows. In a general dynamic macro-model, let the discount factor of the utility function be denoted by  $\beta < 1$ . Then, the Euler equation in the steady state becomes  $\beta R = 1 + z$ . Putting  $R = 1.04$  and  $z = 0.03$  into the equation,  $\beta$  is calculated and found to be 0.99. In other words, setting a growth rate of 3% and an interest rate of 4% is equivalent to setting the discount factor of the utility at  $\beta = 0.99$ .<sup>9</sup>

Productivity by type, denoted by  $e_{i,s}$ , is estimated as follows. First, the gender and age-specific wages of native workers are calculated using supplementary survey data from the “Economically Active Population Survey.” (Statistics Korea, 2015) For immigrants, it is assumed that the relative wage distribution by age and gender is identical to that of Koreans for each visa type, but weights are applied so that there is a gap in the scale. Weights are computed using data for average monthly salary by visa type from the “Survey on Immigrant’s Living Conditions and Labour Force.” The wage weights by visa type are listed in Table 8.

The ratio of the labor force to the non-labor force in the population by age, gender, and visa type in the initial economy is set using data from the “Economically Active Population Survey” and the “Survey on Immigrant’s Living Conditions and Labour Force” for natives and immigrants, respectively. As mentioned above, when an agent becomes 19 years old, it is determined whether she is economically active or not,

TABLE 7—CALIBRATION ON WAGE

Parameter	Meaning	Value	Note
$W_0$	Efficiency Unit Wage Rate	81.8 Million Won	Targeting GDI to be 1,568 Trillion Won
$z$	Annual Growth Rate of Wage	3%	Author’s choice
$R$	Annual Gross Interest Rate	1.04	Author’s choice

TABLE 8—MONTHLY SALARY AND WEIGHTS RELATIVE TO THE NATIVE

Visa Type	Average Monthly Salary (Won)	Weight (Native = 1)
Non-Professional	1,959,792	0.85
Work Visit	1,851,284	0.81
Professional	2,451,326	1.07
Marriage Migrant	1,704,489	0.74
Permanent Resident	1,918,138	0.84
Overseas Korean	2,000,462	0.87
Other	2,245,608	0.98

Note: The average monthly salary of the native is 2.297 million won, and the weight is the proportion to 2.297. Note that the monthly salary is used only for computing weights, so these monthly salaries are not necessarily equal to those in the model economy.

Source: Calculated using Statistics Korea, “Survey on Immigrant’s Living Conditions and Labour Force.”

government expenditures is adapted to the national accounts of Korea, it is natural for the size of the income to also be adjusted to the total GDI in order for budget-balancing to be feasible.

<sup>9</sup>The solution of the model is very robust to changes of  $z$  and  $R$  as long as the discount factor is fixed at 0.99. For instance, even if a lower growth path is assumed in which  $z = 0.01$  and  $R = 1.02$ , the solution deviates only negligibly.

TABLE 9— CALIBRATION OF LABOR FORCE PARTICIPATION AND UNEMPLOYMENT BY VISA TYPE

Visa Type		LFPR		Unemployment Rate	
		Male	Female	Male	Female
Foreigners	Non-professional (E-9)	99.8%	99.9%	0.0%	1.1%
	Work Visit (H-2)	92.7%	77.5%	4.4%	7.3%
	Professional (E-1~E-7)	99.8%	98.4%	0.6%	0.0%
	Marriage Migrant (F-2-1, F-6)	82.9%	45.9%	6.8%	5.4%
	Overseas Korean (F-4)	79.7%	50.1%	8.9%	5.7%
	Permanent Residence (F-5)	89.2%	67.4%	4.6%	3.8%
	Others	63.0%	27.8%	8.9%	20.7%
Natives		84.6%	61.8%	3.7%	3.6%

Source: Calculated using Statistics Korea, “Economically Active Population Survey” and “Survey on Immigrant’s Living Conditions and Labour Force,” 2015.

and this setting does not change for her lifetime in the model economy. The probability of participating in the labor market for each gender and for both natives and immigrants is calibrated so that it equals the labor force participation rate of 2015 of each group. The unemployment rate for each group is also set by referring to the same source. Table 9 presents the average labor force participation rate and the unemployment rate by visa status in the model.

It is not easy to find appropriate data for measuring the propensity to consume. Thus, propensity to consume is estimated as follows using household consumption expenditure data by age group in the “Household Income and Expenditure Survey” as substitute data.<sup>10</sup> First, using 2015 data, the average consumption expenditure according to the householder’s age is summed up horizontally, and the sum is assumed to be the average lifetime income. Then, using this outcome, the proportion of consumption for each age is computed and used as a proxy for  $\xi_{i,s}$  for each  $(i, s)$ .

It is assumed that there are no differences in consumption propensity by gender, but the propensity to consume of immigrants is assumed to be lower than that of natives considering the fact that a considerable amount of immigrants’ income is known to be remitted to their home countries. Specifically, the propensity to consume for non-professional employment (E-9) and work visitors (H-2), residence for whom is limited to five years, is assumed to be 20.2% of that of natives of the same age. For marriage migrants, their propensity to consume is set equal to that of natives, assuming that they tend to assimilate into the host country. For the other visa types (professional staff, overseas Koreans, permanent residents, and others), their propensity to consume is set to 65.5% of that of age-matched natives.<sup>11</sup>

<sup>10</sup>“Household Income and Expenditure Survey” (Statistics Korea, 2015) includes a variable denoted by “average propensity to consume,” but this is different from the propensity to consume defined in the model of this paper. The average propensity to consume in that survey indicates what proportion of the disposable income of the corresponding age group is used for the consumption expenditure by each period, while propensity to consume in this article refers to the percentage of lifetime income spent at each age.

<sup>11</sup>The ratio of deductions by visa type is sourced from Jung *et al.* (2012; 2013).



### C. Government

#### Government Consumption and Transfers<sup>12</sup>

Government consumption and transfer expenditures ( $g_{i,s}$ ,  $b_{i,s}$ ,  $ub_{i,s}$ ,  $ia_{i,s}$ ) are distributed with regard to each age group, gender, and visa type according to Korean government's settlement of the fiscal year 2015 (Ministry of Economy and Finance, 2016). First, the items in the statement are divided into transfers and non-transfers. Then the amount of non-transfers is categorized as government consumption. If some items in transfers and non-transfers are explicitly intended for a specific age or gender group (e.g., expenditures for elementary schools), then such amounts are assumed to be explicitly given to the corresponding groups.

#### Health Insurance

The benefit for natives by age and gender in 2015 is set based on the "National Health Insurance Statistical Yearbook." Data for immigrants' benefits by age, gender, and visa type could not be obtained, but the ratio of medical expenses per capita for natives and foreigners is available (see Figure 2). Thus, for foreigners, the distribution of the benefit for each age and gender is assumed to be identical to that of natives, and the scale of all types of foreigners' benefits is adjusted so that the native-foreigner share of the total salary is equal to that in the 2015 data. It is also assumed that there are no differences among immigrants according to the type of visa.

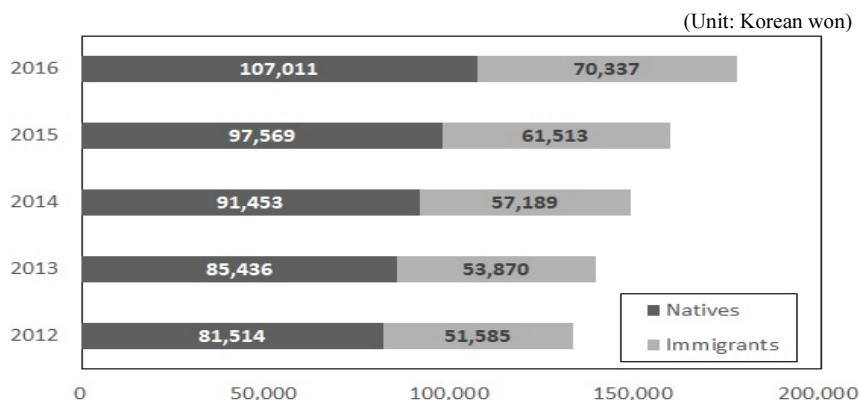


FIGURE 2. AVERAGE MONTHLY MEDICAL EXPENSES FOR THE NATIVES AND IMMIGRANTS

Source: Health Insurance Review & Assessment Service and National Health Insurance Service (2016).

<sup>12</sup>It is very likely that there are major differences between natives and immigrants in terms of benefits from the government. In this study, the types of benefits for which such differences can be identified, fully or partially, are considered. For instance, it is considered that the health insurance benefit to foreigners tends to be smaller than that given to natives of the same ages and gender. However, there are still many types of benefits for which such differences cannot be identified with existing data.

## National Pension

With regard to the national pension, only the old-age pension and lump-sum refunds for non-professional employment and work visitors are taken into consideration, while other parts of the national pension (e.g., disability pension, survivor's pension, and lump-sum for death) are disregarded for simplicity.

To calibrate the pension benefit, a simplified formula is used instead of the actual method for convenience of the analysis, reflecting the current salary formula of the national pension system considering the past income of the recipient and economic income as a policy variable. First, regarding the old-age pension, the simplified formula reflects the pension system of Korea, which is a mixture of the average income of all beneficiaries (hereinafter, the  $A$  value) and the income of individual recipients (hereinafter, the  $B$  value). The formula is set such that the income replacement rate is fixed at 20% over all model periods.<sup>13</sup>

In addition, it is assumed that the maximum benefit rate can be applied to all beneficiaries regardless of the period of subscription to the national pension. Also, it is assumed that benefit payments are made exactly at the age of 65 in all cases.<sup>14</sup> Specifically, the annual benefit of retirees of type  $(i, s)$  in the initial period of the model economy is determined as follows:

$$pen_{i,s} = 0.1 \times (A + B_{i,s})$$

Here,  $A$  represents the annual average wage of all beneficiaries and  $B$  is the present value of the annual average wage earned by a retiree of type  $(i, s)$  before retiring. For instance, if the present value of a beneficiary's past average wage for a type  $(i, s)$  happens to be identical to the overall average, the pension benefit will be exactly 20% of her past income.

Regarding lump-sum refunds, the National Pension Act of Korea indicates that (1) if the foreigner's home country's law gives Korean citizens a corresponding salary equivalent to the lump-sum refund, or (2) if a social security agreement on lump-sum refunds is active, or (3) if the foreigner holds an E-8, E-2, or H-2 visa, then she will receive the principal and interest of her national pension payment during her stay as refunds when she leaves Korea. Based on this, our model also assumes that non-professional employees and work visitors receive lump-sum refunds of their pension payments when they leave the host country after a five-year stay.<sup>15</sup> However, because the labor income tax rate and the pension payment rate are not

<sup>13</sup>The income replacement rate, which is derived through a proportional constant in the original national pension formula, is 46.5% as of 2015, and is designed to reach 40% in 2028 by decreasing by 0.5%p every year. However, this is the nominal replacement rate assuming 40 years of entitlement in the national pension. In reality, Korea's national pension is not sufficiently mature, and it is practically impossible to join the national pension for 40 years due to retirement or other reasons. Therefore, the actual replacement rate is estimated to be around 20% in the literature. For example, the actual replacement rates of national pensions are estimated at 16.9%, 18.56%, and 23.98% in Shin (2015), Kim and Kwon (2016), and Woo *et al.* (2016), respectively. In the model used here, a defined benefit type of formula is assumed in that a real replacement rate of 20% is guaranteed.

<sup>14</sup>In reality, the rate of the benefit varies depending on the duration of entitlement, and the age of receipt is also set to a period of 60 to 65 years old instead of setting it at a certain age.

<sup>15</sup>In reality, Korean citizens can receive a lump-sum refund due to reasons such as an insufficient entitlement period. In the model, however, all beneficiaries except non-professional employees and work visitors are assumed not to select this option but to receive pension benefits only in the form of old-age pensions.

differentiated in this model, the exact amount of the lump-sum refund should be set arbitrarily outside the model. In the model, it is assumed that the foreign worker receives a value equal to the annual income (equivalent to the B value of the national pension benefit formula) multiplied by the average income replacement rate of the national pension, i.e.,  $0.2 \times B_{i,s}$ .<sup>16</sup>

## Government Debt and Taxation

This study assumes a hypothetical government account that combines the government's general accounts with major funds (National Pension Fund, WCI, and Employment Insurance Fund).<sup>17</sup> Thus, the government debt in the model is the government debt in the actual general account minus the sum of the national pension fund, the WCI fund (industrial accident insurance fund), and the employment insurance fund. As of the end of 2014, the government debt is approximately 527.1 trillion won, the national pension fund is 469.8 trillion won, the employment insurance fund is 7.6 trillion won, and the WCI fund is 10.2 trillion won. Therefore, the government debt of the initial period in the model economy is approximately 39.5 trillion won.<sup>18</sup>

The tax system of this model consists of the average income tax rate ( $\tau_l$ ) and average consumption tax rate ( $\tau_c$ ). Although  $\tau_l$  is expressed such that it refers to the tax rate on labor income, it is actually different from the actual labor income tax rate in reality. In this model, taxes on capital income, such as corporate taxes and employers' contributions to social insurance, are not explicitly considered. Therefore, the term "income tax rate" is used throughout this article instead of the term "labor income tax rate." Therefore, it is more reasonable for the income tax rate here to be interpreted as a concept covering taxes on both labor and capital income and the contributions to various social security schemes.

Indeed, the average effective tax rate calculated by the method of Mendoza *et al.* (1994) using the national accounts and tax revenue data for 2015 for Korea is 25% for the labor income tax and 11% for the consumption tax. However, as mentioned above,  $\tau_l$  in this model is different from the labor income tax rate conceptually, and this combination does not satisfy the above-mentioned government IGBC condition (Equation (1)), and given that  $\tau_l = 0.25$  and  $\tau_c = 0.11$ , Korea's current debt level is not sustainable in the model economy. Therefore, the IGBC conditions should be adjusted by changing the consumption tax rate and income tax rate. In this paper, the consumption tax rate is fixed at 11% and the income tax rate is adjusted for balancing

<sup>16</sup>The payment rate for individual employees into the national pension is 4.5%, and the non-professionals and work visitors in the model stay in Korea for five years. By simple algebra, the lump sum is 22.5% of the annual income. Considering there are blind spots in the pension system, 20% is assumed to be a figure which measures immigrants' fiscal contributions quite conservatively.

<sup>17</sup>Regarding other funds such as the private school pension fund, they are considered to be relatively unrelated to immigration policy, even if the amounts are large. Thus, they are not included in the government account in this study.

<sup>18</sup>In this model, the sum of future primary balance changes very sensitively to changes in the income tax rate. Therefore, regardless of whether the initial debt is 39.5 trillion won or 527.1 trillion won, the difference in the equilibrium tax rate is less than 0.2%, meaning that the model is very robust to the level of initial debt.

the budget constraint.<sup>19</sup> The income tax rate induced by this equilibrium condition is calculated and found to be approximately 39.3%.<sup>20</sup>

## V. Results of Equilibrium Analysis

### A. Definition of Fiscal Contribution and Its NPV

When consumption, hours worked, and government taxation and fiscal expenditures are realized in equilibrium, the contribution of each type of agent to the government's fiscal soundness can be calculated. The fiscal contribution of type  $(i, s)$  in the initial period of the economy ( $t = 0$ ) is denoted as  $fc_{i,s,0}$  and is defined as follows:

$$\begin{aligned} fc_{i,s,0} = & \tau_c \cdot c_{i,s,0} + \tau_l \cdot W_0 \cdot e_{i,s}(1 - u_{i,s}) - g_{i,s} - b_{i,s} \\ & - hc_{i,s} - ia_{i,s}e_{i,s}(1 - u_{i,s}) - ub_{i,s}e_{i,s}u_{i,s} - pen_{i,s} \end{aligned}$$

In other words, the fiscal contributions of agents of type  $(i, s)$  correspond to taxes levied on these agents minus government expenditures caused by or paid to them (government consumption, transfers, health insurance benefits, WCI benefits, unemployment benefits, and pension benefits). If this value is positive, the agents are considered to contribute to the government's finances in this period, whereas if it is negative, the fiscal burden is then greater than the contribution of the agents to the fiscal status of the government.

However, the fiscal contribution calculated in this way is only a measure of the fiscal contribution of an agent at a particular point in time. An agent will not have the same fiscal impact in the future. For example, if a 60-year-old immigrant enters the country and has a job, the fiscal contribution may be positive at the moment, but if she retires in only a few years and becomes old, the contribution will be negative thereafter. Therefore, it is necessary to sum them over time for more reasonable analyses. For this purpose, the NPV (net present value) of the fiscal contribution of the type  $(i, s)$  is calculated. In other words, we sum up the present value of the future fiscal contribution of each type of agent over time in order to evaluate the agents' lifetime contributions as of a period. Technically, the NPV is calculated by initially computing the NPV of a newborn (0 years old) and then calculating the NPV of the remaining agents using the newborn's NPV. The detailed procedure is shown below.

Let the NPV of type  $(i, s)$  at  $t = 0$  be denoted by  $npv_{i,s}$ . As described above, the type element  $s$  consists of gender, labor market participation, visa type, and age at the time of immigration. Let  $m$  and  $f$  be subsets of  $s$ , let  $m$  be all types

<sup>19</sup>Alternatively, the balance can be met by fixing the tax rates and adjusting government spending or pension schemes.

<sup>20</sup>This tax rate may appear to be excessively high considering that the effective payroll tax rate in Korea is usually estimated to be less than 20%. However, note that  $\tau_l$  in this study does not imply a labor income tax rate but a (consolidated) income tax rate, including not only labor income but also capital income. Considering this, the gap between the actual rate and the model rate becomes significantly smaller.

of males, and let  $f$  be females. Then,  $npv_{0,m}$  and  $npv_{0,f}$ , NPV of male and female newborns, respectively, can be derived by solving the following simultaneous equations:

$$(2) \quad \begin{aligned} npv_{0,m} &= \sum_{i=0}^{99} \Pi_{i,m} R^{-i} \left[ fc_{i,m,i} + \varphi_{i,m} (1+z)^i \left\{ \frac{105}{205} npv_{0,m} + \frac{100}{205} npv_{0,f} \right\} \right] \\ npv_{0,f} &= \sum_{i=0}^{99} \Pi_{i,f} R^{-i} \left[ fc_{i,f,i} + \varphi_{i,f} (1+z)^i \left\{ \frac{105}{205} npv_{0,m} + \frac{100}{205} npv_{0,f} \right\} \right] \end{aligned}$$

Here,  $\varphi_{i,s}$  represents the corrected birth rate of type  $(i,s)$ ,<sup>21</sup> and  $fc_{i,s,t}$  is the fiscal contribution of type  $(i,s)$  at time  $t$ . In the equations,  $\Pi_{i,m}$  and  $\Pi_{i,f}$ , the unconditional probability of survival at age  $i$  for each gender, are used because the unconditional and conditional probabilities are equal for a newborn child.

The implications of equation (2) are as follows. First, when a child is born, he or she will contribute as much as  $fc_{i,m,i}$  every year during their life. Accordingly, the present value of this part is taken into account. Secondly, the second term of the square bracketed term considers the value of the children that this newborn may have in the future. He or she contributes to birth with probability  $\varphi_{i,s}$  at the age  $i$ , and the child born is a boy with a probability of 105/205 and a girl with probability of 100/205, as mentioned in the previous section on calibration. Because there are two equations with two unknowns, the NPV for newborns of both genders can be solved.

After calculating the NPV of the newborn, the NPVs of the remaining agents can be calculated using the fact that all newborn children are considered to be natives regardless of their parents' nationalities.

$$npv_{i,s} = \sum_{j=i}^{99} \frac{\Pi_{j,s}}{\Pi_{i,s}} R^{-j} \left[ fc_{j,s,j-i} + \varphi_{j,s} (1+z)^j \left\{ \frac{105}{205} npv_{0,m} + \frac{100}{205} npv_{0,f} \right\} \right]$$

## B. Results of Analysis

### Fiscal Contribution by Type

Before looking at the NPV, the distribution of the fiscal contributions by age for each type of agent as of 2015 ( $fc_{i,s,0}$ ) is demonstrated. First, Figure 3 compares the average fiscal contribution of foreigners with Korean natives by age. The vertical

<sup>21</sup>Here, the fertility rate is corrected such that we apply only half of fertile women in the actual data to the women's contribution, with the other half applied as the males' contribution. In other words, this is similar to assuming that all children are born only between couples consisting of a male and a female. We also apply half of the female births to males who are two years older instead of males of the same age, considering the average ages of a husband and wife in Korea. This approach is different from that of Storesletten (2003), in which all NPVs through birth are assumed to be exclusively the females' contribution.

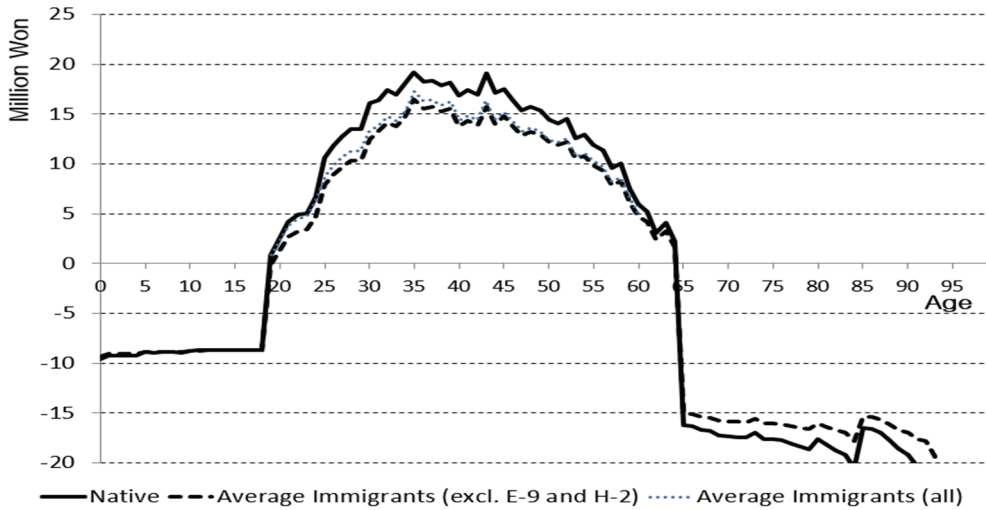


FIGURE 3. PER-CAPITA FISCAL CONTRIBUTION OF THE NATIVE AND IMMIGRANTS

axis in the figure indicates the average per-capita fiscal corresponding to each age. For example, a 0-year-old Korean native is estimated to have a fiscal contribution of about -9.6 million won, while a 40-year-old Korean native is estimated to make a fiscal contribution of about 16.9 million won. In other words, the average contribution of the per-capita income tax and consumption tax for a 40-year-old Korean native is greater than the government's financial burden per capita by about 16.9 million won.

In the range of working age (19-64 in the model), both natives and immigrants show positive (+) fiscal contributions, indicating that the tax revenues from these groups in that age range exceed the government's financial burden. Because the productivity of natives is assumed to be higher than that of foreigners on average, native Koreans make higher fiscal contributions than foreigners during their working years. On the other hand, for those aged 60 or older, this relationship is reversed, and the natives cause more of a financial burden. This occurs because natives have higher incomes during their working years than immigrants. Because natives have made more pension and health insurance contributions than immigrants, they are paid more after their retirement and exhibit smaller fiscal contributions than immigrants.

Figure 4 and Figure 5 show the breakdown of the fiscal contribution of foreigners by visa type. First, Figure 4 compares the per-capita fiscal contributions of professional staff (E-1~E-7) and overseas Koreans (F-4) to that of Koreans. For professional staff, they exhibit higher productivity and labor force participation rates than those of the natives on average. Therefore, their fiscal contribution in the working-age group is approximately 1.5~2 times higher than that of the natives. On the other hand, for overseas Koreans, the average fiscal contribution of the working-age group is slightly smaller than that of the natives given that their average wage is lower than that of the natives.

Next, Figure 5 shows the fiscal contributions of marriage migrants (F-2-1, F-6), permanent residents (F-5), and others. Permanent residents make similar fiscal contributions to natives, while marriage migrants and others make lower fiscal contributions than natives. For marriage migrants, they have the lowest productivity

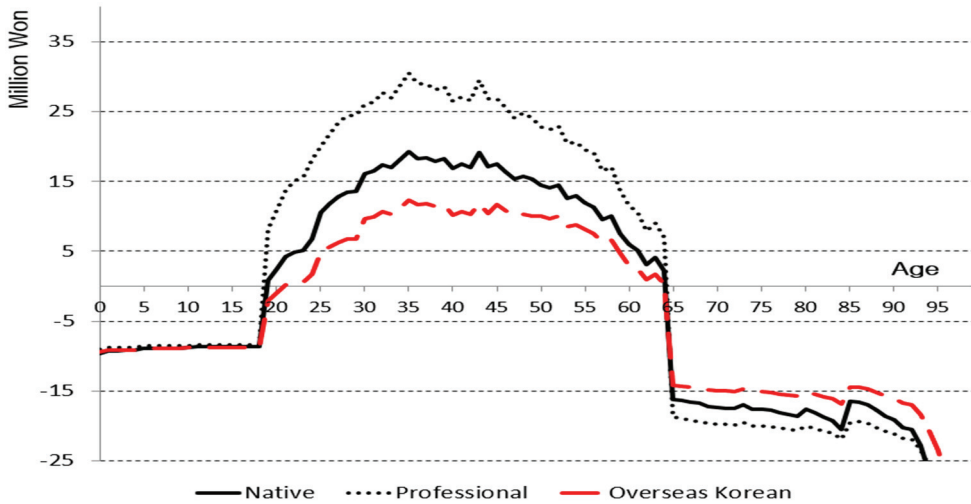
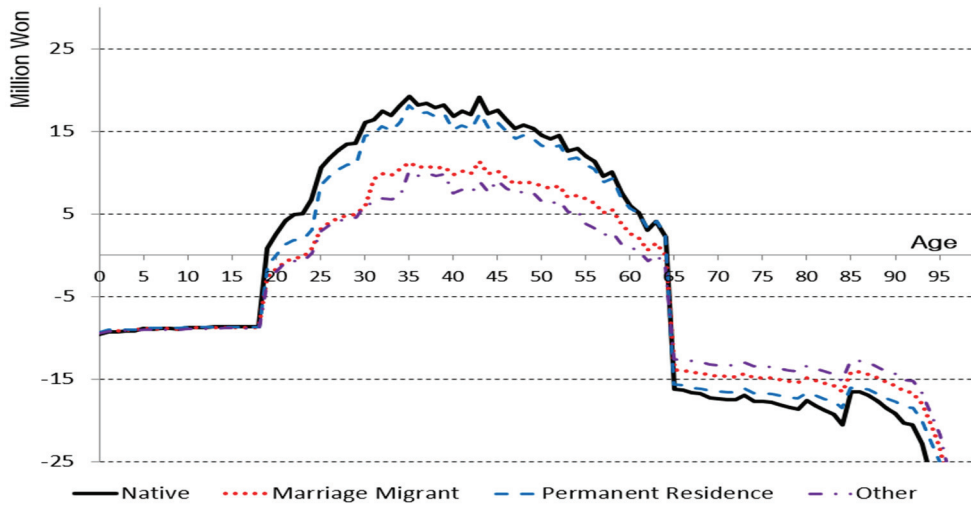


FIGURE 4. FISCAL CONTRIBUTION BY VISA TYPE – THE PROFESSIONAL AND OVERSEAS KOREANS

FIGURE 5. FISCAL CONTRIBUTION BY VISA TYPE –  
MARRIAGE MIGRANT, PERMANENT RESIDENCE, AND OTHER

among the visa types considered in this study; hence, their contributions by paying taxes and social security are smaller than those of the natives. For the other visa types, although their average productivity is higher than that of marriage migrants, they exhibit the lowest labor force participation rate among all visa types. Thus, the average fiscal contribution for their working-age group is relatively low.

Lastly, we examine the fiscal contributions of non-professionals (E-9) and work visitors (H-2), who are assumed to stay for five years and then leave. In this case, the period of stay affects the fiscal contribution due to the lump sum return of the pension, and other factors. Figure 6 compares the per-capita fiscal contributions of the first-year non-professionals and work visitors to those of the natives. As shown in the figure, non-professionals show higher fiscal contributions than average natives, but this amount is slightly lower than that by native employees due to the

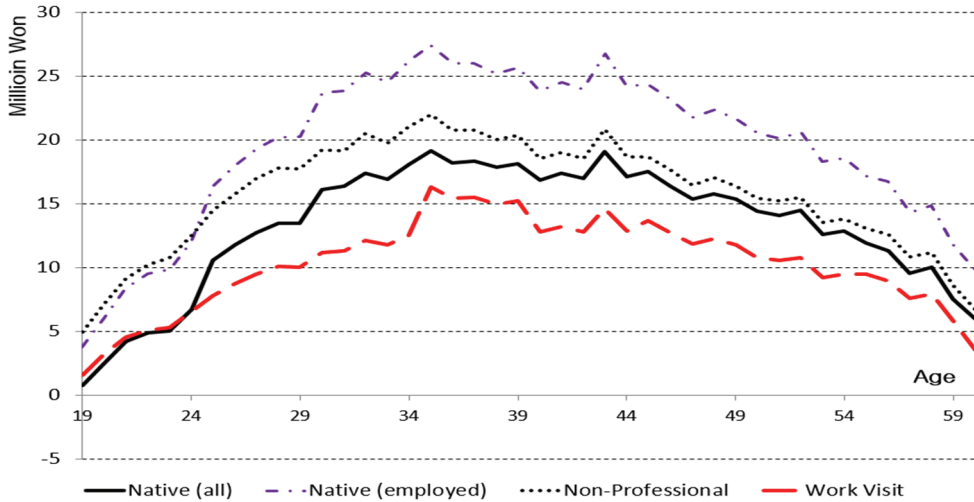


FIGURE 6. FISCAL CONTRIBUTION BY VISA TYPE – THE NON-PROFESSIONAL AND WORK VISIT

wage gap. Regarding work visitors, despite their high labor force participation rate, they show lower fiscal contributions than even the average natives.

### NPV of the Future Fiscal Contribution

As mentioned earlier, the fiscal contribution ( $fc_{i,s,t}$ ) is a measure of how much an agent of a particular type contributes to the government's fiscal soundness for a certain period, but this alone cannot be a measure of the fiscal contribution of an agent. Even if an immigrant makes a positive fiscal contribution for a certain period, it should also be considered how much of a fiscal burden will arise if he/she lives in the host country past their retirement. Moreover, if a birth occurs in the host country, the fiscal contribution made by the immigrants' descendants should also be considered. In order to determine the long-term effects of immigrants on public finances, the NPV of the fiscal effects must be included in the analysis for not only the instantaneous effects but also for the long-term effects.

Figure 7 illustrates the result after computing the average NPV of the natives by age. The average per-capita NPV for a newborn is estimated to be about 161.6 million won, which is a positive number.<sup>22</sup> This means that the fiscal contribution (taxes and social security payments) that a child newly born in 2015 is expected to make on average is expected to be larger than the fiscal burden caused by him/her by 161.6 million won (according to the 2015 value). For the average Korean, it is estimated that the NPV is positive until the age of 42. After 43, the present value of the tax burden to be paid by the economic entity catches up to the government spending caused by him/her.

<sup>22</sup>For reference, Storesletten (2003) conducted a similar study on Sweden and found that the NPV of a Swedish native newborn is around -46,000 kroner (about -6 million Korean won). If the NPV of a newborn is negative, one may doubt whether such an economy can be fiscally sustained. However, it is theoretically possible, as the NPV of Swedes of working age is positive given that the net fiscal gain of the working-age population in the initial period can compensate for the net fiscal burden of the newborns in the future.



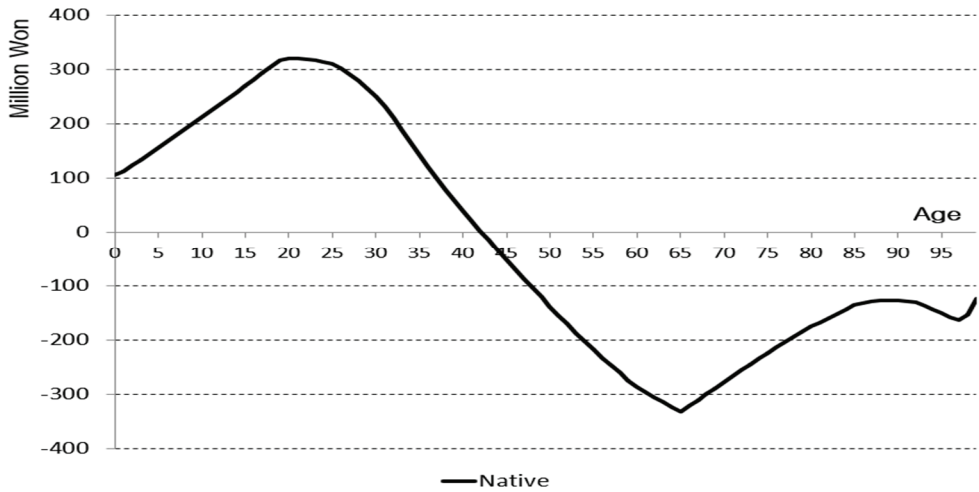


FIGURE 7. NPV FOR THE NATIVE

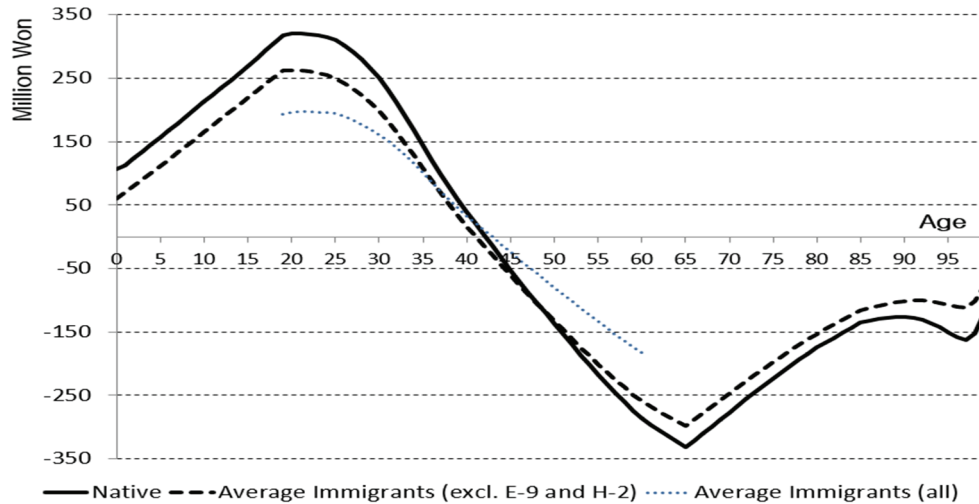


FIGURE 8. NPV FOR THE NATIVE VS. IMMIGRANTS

Figure 8 compares the NPV of average Korean to that of the average immigrant by age. When only considering immigrants with visas excluding non-professional employment (E-9) and work visit (H-2) types,<sup>23</sup> the NPV of the native becomes negative from the age of 43, while that of the average immigrant (excluding those holding E-9 and H-2 visas) becomes negative from the age of 42. The NPV of Koreans tends to be slightly larger than that of immigrants in the range where the NPV is positive. In order for the comparison to be more visible, the average NPV of a 0-year-old immigrant is compared with the NPV of a newborn, although immigration at 0 years old is not very realistic. The NPV of a 0-year-old immigrant

<sup>23</sup>Because E-9 and H-2 visa holders generally do not migrate to Korea outside of their working ages, the age-specific NPV of all immigrants cannot be computed. Therefore, the average NPV for all immigrants is only computable for the working ages (19–64).

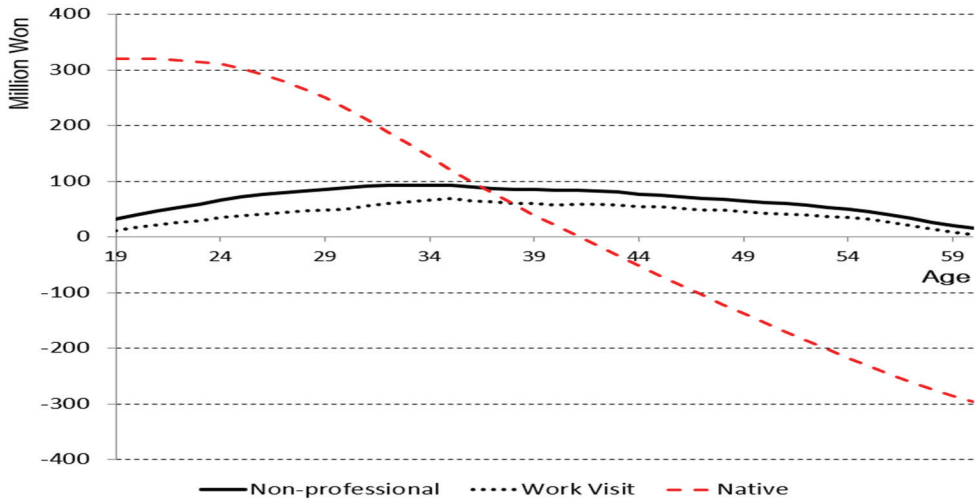


FIGURE 9. NPV OF THE NON-PROFESSIONAL AND WORK VISIT

is only 60.2 million won, which is lower than that of a 0-year-old Korean newborn, as the average productivity and the labor force participation rate of the immigrants are both smaller than those of natives during their working years. Considering the overall immigrants' average including E-9 and H-2 types, the average NPV of immigrants up to their 40s is lower but the transition from positive to negative is delayed because non-professionals and work visitors are short-term workers leaving Korea before their retirement. Because they mostly conduct economic activities and leave Korea before retirement, their NPVs are always positive.

Figure 9 demonstrates this more clearly. It compares the age-specific NPV of Koreans to those of non-professionals and work visitors directly. For native Koreans, the NPV up to their mid-30s is much higher than those of non-professionals and work visitors. However, as the age increases, the NPV of native Koreans declines sharply, while the NPVs of non-professionals and work visitors exhibit a stable path over time.

Figure 10 and Figure 11 show the NPVs of immigrants holding the remaining visa types. The immigrants with professional staff visas (E-1~E-7) during their working years exhibit high NPVs nearly twice as high as that of natives, and the value remains positive up to the age of 46 due to their high productivity and labor force participation rates. Meanwhile, the NPV of permanent residents (F-5) is similar to that of native Koreans. Overseas Koreans (F-4), marriage migrants (F-2-1, F-6), and others show lower NPVs than that of native Koreans.

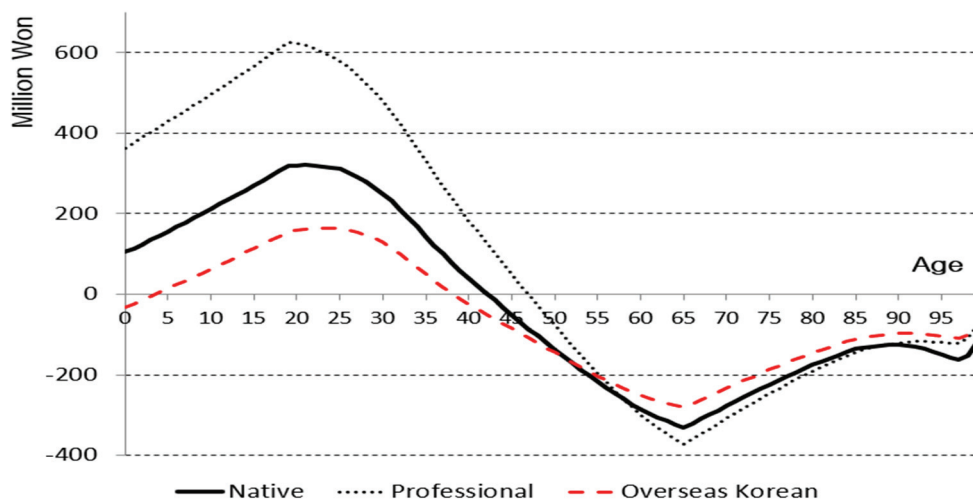


FIGURE 10. NPV OF THE PROFESSIONAL AND OVERSEAS KOREAN

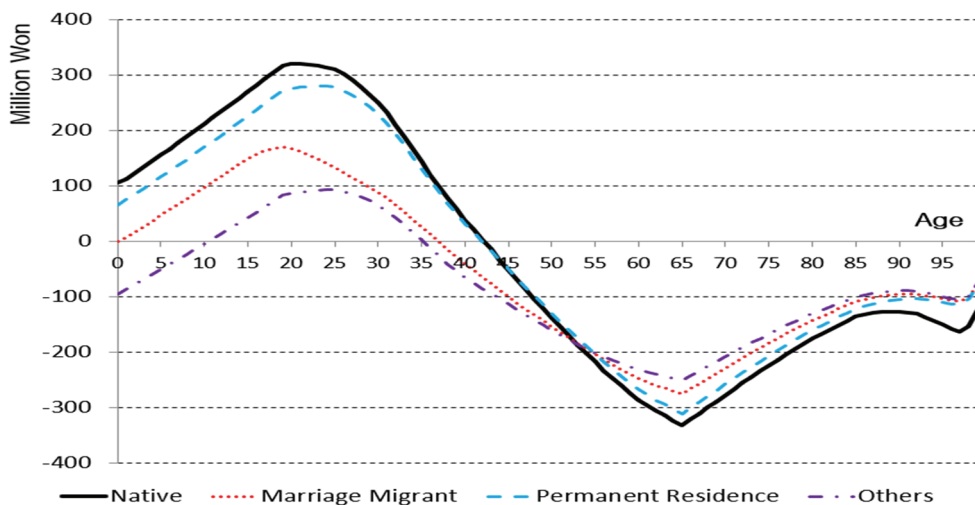


FIGURE 11. NPV OF MARRIAGE MIGRANTS, PERMANENT RESIDENCE, AND OTHERS

### NPV of Fiscal Contribution and Its Policy Implications

As shown above, the fiscal contribution and its NPV varies by age and visa type given that productivity and labor market participation rates vary. Table 10 summarizes the ranges of ages in which the NPV is estimated to be positive by visa type. The non-professionals and work visitors exhibit positive NPVs during their stay due to their characteristics as short-term workers, while the remaining types exhibit different ranges according to the productivity, labor market participation, and unemployment rates.

First, for the non-professionals and work visitors, the NPV is positive for all ages between 19 and 64. Because they are a short-term cyclical workforce, they generally leave the country before they retire and gain a benefit from the host country's welfare

TABLE 10—RANGE OF AGES WITH POSITIVE NPVs BY VISA TYPE

Visa Type	Range of Ages with Positive NPV		Largest NPV (Corresponding Age)
	From	To	
Non-professional	19	60	93.12 million won (34)
Work Visit	19	60	68.73 million won (35)
Professional	0	46	625.99 million won (19)
Marriage Migrant	1	36	170.70 million won (19)
Overseas Korean	4	38	164.31 million won (24)
Permanent Resident	0	41	280.73 million won (24)
Other	11	35	93.50 million won (24)
Native	0	41	236.13 million won (21)

*Note:* For the non-professional and work visitors, only immigrants of ages 19–60 are considered. In other words, this table implies that all ages of the non-professional and work visitors exhibit positive NPVs.

state, while they pay taxes and fees during working in Korea due to their high participation and employment rates.

For those holding the remaining types of visas, no immigrants over 50 have positive NPVs for any type, and in particular, marriage migrants, overseas Koreans, and the other types start to have negative NPVs from their the mid- to late 30s. There are also differences in the starting ages of positive NPVs by visa type. For professional staff and permanent residents, immigrants of age 0 have a positive value, while the starting ages are 1 to 11 for the remaining visa types. This pattern has implications similar to those of the results of Storesletten (2000), in which only mid- and high-skilled immigrants aged 20 to 50 years have positive NPVs, and Storesletten (2003), which showed positive NPVs from average immigrants aged 20 to 30, while the range is slightly wider in this study than in those. Immigrants who are young and have a high degree of skill are estimated to make a high fiscal contribution, but if immigrants are excessively old or young, they show a net fiscal burden.

Next, using the estimated NPV by age and visa type, the total NPV of the actual immigrants in Korea as of 2015 is calculated. The total NPV for each visa type is computed by multiplying the number of immigrants of each type by the corresponding NPV and then summing up these values for each visa type. Table 11 displays the results. As indicated in the table, the total NPV of the total population

TABLE 11—SUM OF NPVS FOR EACH VISA TYPE USING ACTUAL NUMBER OF IMMIGRANTS (2015)

Visa Type	Number of Immigrants	Sum of NPVs (Trillion Won)
Non-professional	264,584	11.1
Work Visit	287,831	6.4
Professional	46,981	17.6
Marriage Migrant	124,301	-16.3
Overseas Korean	300,931	-22.9
Permanent Resident	111,387	-5.7
Other	141,005	-5.4
All Immigrants	1,277,020	-15.1
Natives	49,710,452	994.4
Sum	50,987,473	979.3

of Korea, including both natives and immigrants, is estimated to be approximately 979.3 trillion won as of 2015. The net fiscal contribution of native Koreans is 994.4 trillion won, and the sum of the net contribution of foreigners is -15.1 trillion won, implying that the present value of future fiscal contribution of an average immigrant into Korea is negative.

By visa type, the NPVs of non-professionals and work visitors are estimated to be 11.1 trillion won and 6.4 trillion won, respectively, implying that they are net contributors to Korea's fiscal soundness. For professional staff members, their average NPV per capita is 2~3 times higher than that of natives, but their total population size is small and the total NPV is only 17.6 trillion won. For all other visa types, the sum of the NPVs is negative. For marriage migrants, overseas Koreans, permanent residents, and others, their average NPV per capita tends to be positive before their mid-30s. However, their total NPV is calculated as a negative number because their ages tend to be high and their labor participation rates low.

This result suggests that the current immigration policy of Korea has not achieved positive effects at least fiscally. In fact, immigrants who can contribute to Korea's finances are those who are younger than their mid-30s and participate in the labor market, whereas immigrants who actually stay in Korea tend to incur net fiscal costs due to their high ages or low economic participation rates. More importantly, the fact that the sum of all immigrants' NPVs is negative indicates that an immigration policy that only increases the number of immigrants while maintaining the current population structure may result in a worsening of Korea's fiscal situation.

In conclusion, in order for the future immigration policy to have a positive effect on the fiscal side, it is necessary to make an effort to change the current immigration influx population structure. In order to predict the mitigation of fiscal problems by an influx of immigrants, it is necessary to adopt a selective immigration policy that considers immigrants' productivity rates, ages, and durations of stay. The immigration policy must concentrate on allowing in those in their 30s or younger, and visas need to be issued more generously for foreigners with professional capabilities and high productivity. Also, regarding low-productivity foreigners, efforts should be made to avoid fiscal losses by maintaining the principle of short-term recruitment. These results and policy implications are in line with existing studies on immigration in other economies, such as the United States and Europe. Instead of an immigration policy only for rebalancing the numerical demographic structure due to aging, it is important to focus on the qualitative factors of potential immigrants, such as their productivity rates, ages, and willingness to participate in the economy.

## VI. Concluding Remarks

In this article, the present situation and characteristics of immigrants staying in Korea based on various types of available data are studied and the fiscal contributions according to different visa types, ages, and economic statuses are estimated. Through this model analysis, the desirable direction of future immigration policy is sought in a fiscal sense.

According to the estimation of the fiscal contributions of immigrants by age and

visa type, it is confirmed that there are significant differences in the fiscal contributions of immigrants according to their visa type and age. For instance, professional staff members are estimated to make significantly higher fiscal contributions over a wider age range than that of native Koreans. On the other hand, marriage migrants and overseas Koreans make lower fiscal contributions than native Koreans, and except for certain age groups, such as those in their 20s, they cause more of a fiscal burden relative to their contribution. This implies that a selective immigration policy that considers the qualitative aspects of potential immigrants is more desired than simply considering the age structure of immigrants for the purpose of mitigating population aging.

The implications and limitations of this study are as follows. First, this study is meaningful in that the fiscal contributions of immigrants entering Korea are estimated using a quantitative model that reflects the actual fiscal system and visa issuance system in Korea. Most existing studies of immigration tend to focus on the labor market effects or on socialization, and not many in Korea deal with immigration in light of the government's fiscal aspects. However, there are many aspects that do not reflect reality due to limitations of data or for technical reasons. For example, this model assumes a very restrictive form of return migration only for non-professionals and work visitors and does not reflect the fact that many immigrants with all visa types return to their home countries in reality. In addition, government taxation and social security fees are reflected in the model only in a simplified form due to the lack of data for realistically estimating the income distribution of immigrants. Finally, this model assumes only a single government account, while there are the general account, special accounts, and funds of the central government, as well as a number of local government accounts. By simplifying this, the effects of immigration on each account, such as the national pension fund, cannot be analyzed. These limitations are mainly due to the lack of data regarding the economic activities of foreigners, such as the distribution of income by visa type, their consumption expenditures, and other factors. Other limitations omitted here are expected to be considered in future studies.

Finally, this study does not intend to claim that immigration policies should be determined solely by the size of the fiscal contributions made by immigrants. When actually setting immigration policy, various factors, such as human rights issues, should be considered in addition to economic aspects.

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## Effects of US Monetary Policy on Gross Capital Flows: Cases in Korea<sup>†</sup>

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*U.S. monetary policy has been claimed to generate global spillover and to destabilize other small open economies. We analyze the effects of certain identified U.S. monetary shocks on gross capital flows in the Korean economy using the local projection method. Consistent with previous results on other small open economies, we initially confirm that U.S. interest rate hikes are dynamically correlated with foreign outflows and residents' inflows. That is, not only are they correlated with withdrawals by foreigners but they are also correlated with those by domestic (Korean) investors. The results are mostly driven by portfolio flows. Second, however, the marginal response to a U.S. monetary policy shock is, on average, subdued if we focus on the sample periods after the Global financial crisis of 2007-2008 (henceforth, global financial crisis). We conjecture a possible reason behind the change, an institutional change related to financial friction. If the degree of pledgeability of the value of net worth increases, the marginal responses by both investors would drop with a U.S. monetary policy shock, consistent with our findings.*

Key Word: U.S. Monetary Policy Spillovers, Gross Capital Flows,  
Local Projections, Financial Frictions  
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### I. Introduction

The foreign effects of U.S. monetary policy has been among the most important topics in the open macroeconomics literature over the past decade. In a small open economy, volatile capital flows caused by external shocks play a central role in destabilizing macroeconomics. Consequently, they have been major concerns, not only by scholars but also by policymakers. Especially during the period of time referred to

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here as the ‘great financial crisis’, the destabilizing effects of U.S. monetary policy shocks and the concurrent risk aversion and liquidity spillover to other economies have been widely debated. What has been termed the global financial cycle and subsequent investor sentiments are claimed to fluctuate with U.S. monetary policy.<sup>1</sup> To understand how a U.S. monetary policy shock can spillover to other small open economies is clearly crucial to understand not only the determinants of capital flows but also to the overall macroeconomics dynamics.

In this article, we analyze the effects of a US monetary policy shock on Korean *gross* capital flows. A vast amount of literature covers new stylized facts regarding the determinants of gross capital flows in emerging or small economies. However, although Korea has been one of the most open economies in terms of both the trade and financial sectors, we do not have a sufficient understanding of the effects of U.S. monetary policy on capital flows in Korea. Accordingly, there remains no consensus on the topic. The East Asian crisis is the textbook balance of payment crisis with a bank runs on emerging economies. Moreover, the global financial crisis hit the Korean economy relatively hard. While the importance of the external sectors and capital flows has never been underestimated in determining fiscal and monetary policy, the effects of U.S. monetary policy on *gross* capital flows has been missing from the debate. Also, while it has been claimed that the capital flows of the Korean economy are more resilient to external shocks after the global financial crisis, not many attempts have been made to assess the merits of such a statement systemically.

Using the local projection method on *gross* capital flows and with an identified U.S. monetary policy shock, we fill this gap. In a nutshell, we confirm that the patterns in Korea are consistent with those in other small open economies. We first identify US monetary policy shocks on a quarterly basis, as in Iacoviello and Navarro (2019). We then find, before the global financial crisis, that U.S. monetary policy hikes, tightening shocks on the U.S. federal funds rate, are correlated, not only with capital outflows by foreign investors but also with capital inflows by Korean residents who hold the asset position externally.<sup>2</sup> In the baseline specification before the crisis, we confirm that if U.S. monetary policy increases by one hundred basis points, foreign investors pull their positions out of Korea, with the foreign liability position decreased by 13.8 percent. At the same time, domestic investors retrench their positions and inflow capital, and the external asset position is decreased by 4.8 percent. Thus, a U.S. monetary policy shock is associated with decreases in *gross* capital flows. However, overall, the degree of inflows by residents is smaller than the level of outflows by foreigners, and net capital flows mark deficits (net outflows) with a U.S. monetary policy shock. Upon a local projection analysis of gross capital flows, we distinguish FDI, portfolio and other flows of both foreigners and local residents. We note that the overall flows are mostly driven by portfolio flows. Unlike earlier works which stress the role of banking flows, we could not find meaningful results with regard to other flows, i.e., mainly banking flows.<sup>3</sup>

<sup>1</sup>Furthermore, Miranda-Agrippino and Rey (2020) also claim that it is not feasible to cope with those by means of conventional monetary policy or exchange rate policies.

<sup>2</sup>For further discussions on gross capital flows and the related terminology (surges, flights, stops, and retrenchments) please see Forbes and Warnock (2012).

<sup>3</sup>We note that these results are even different from the results of the companion article, Choi (2020). In the previous article, preceding the current article, most of the stand-out results are for other (banking) flows. We will discuss this difference later in sections IV and V.

Second, we provide a consistent result that supports the prior contention that the effects are smaller after the global financial crisis. If we focus on the sample periods after the crisis, the overall patterns of the capital flows are broadly consistent; both foreign and domestic investors withdraw their external positions upon the shock. However, marginal response to a U.S. monetary policy shock is much smaller than it was earlier. If U.S. monetary policy increases by one hundred basis points, on average, foreign investors decrease their positions in Korea by 4.8 percent, while domestic investors decrease their foreign positions by 2.9 percent. Although the evidence does not provide any statistical inference, the magnitudes are on average smaller than the average responses in the periods before the crisis.<sup>4</sup>

Our results contribute to the ongoing debate in several ways. First, we confirm that (in our base line specification) gross capital also matters in Korea, as in other small economies. As international capital claims are much more bilateral than ever before, the importance of gross capital flows has been stressed by many scholars. Unlike previous wisdom, international investors have cross-hold claims on each other much more than before. Consequently, Broner *et al.* (2013) claim that domestic investors play a much greater role as financial integration evolves and generates very different dynamics compared to a situation in which net flows are mostly driven by international investors. Thus, when not taking gross positions into account, we may miss important dynamics of capital flows. Along with the identified U.S. monetary policy which disentangles only the unexpected component of rate changes of U.S. federal funds, to understand the behavior of residents is critical. Retrenchments of capital imply that they do not simply react to simple interest rate differentials between the U.S. and a small open economy. The literature, which only focused on interest rate differentials on net capital flows, would predict net outflows of small open economies. However, this would not be able to account for capital inflows by residents.

We also note that our results are consistent with the claim that the Korean economy is less vulnerable to external shocks. Many scholars, policymakers, and participants in capital markets argue that capital flows in Korea have become apparently more resilient to external shocks after the global financial crisis. Although the 'taper tantrum' of 2013 hit many emerging economies and drove abrupt capital outflows, the country did not engage in the typical response of an emerging economy. Capital indeed flowed into Korea, while other emerging economies such as Turkey suffered significant outflows during the event. Moreover, despite the heightened volatility in global financial markets in 2018, Korea had strong capital inflows. Based on these outcomes, IMF Article IV in 2019 stated that

*"[...]the episode was suggestive of occasional safe-haven patterns in the demand for Korean debt securities[...]".*

Although the possibility has repeatedly been raised by many people, no attempts have been made to compare the elasticity of capital flows. Our paper also does not provide any rigorous statistical inferences, but we do see that the marginal responses

<sup>4</sup>It should be noted that we do not provide statistical test results that confirm the differences. One cannot directly map and compare the confidence intervals of the two different samples. Thus, we posit no statistical inferences.

to a U.S. monetary policy shock are on average quite different. We claim that these outcomes support the prior belief that the responsiveness of capital outflows is much lower.

We apply the local projection method to estimate the impulse response of identified U.S. monetary policies on gross capital flows. After being introduced by Jordà (2005), the local projection approach quickly became the standard methodology to analyze impulse response outcomes. Instead of specifying a system of equations when calculating the impulse response to a shock, the local projection method projects the impact of a shock on the response variable locally; by extending the period between the moment a shock is applied and the response variable reacts, the local projection method directly estimates the dynamic impulse response of the variable of interest. Because we are interested in the disaggregate component of capital flows along with the overall flow, it is more appropriate to apply the local projection method to each flow independently than to use the VAR. In addition, because we previously identified a U.S. monetary policy shock based on Iacoviello and Navarro (2019), we do not need to hinge on further identification. Thus, local projection will serve as a simple but powerful econometric methodology.

Various interpretations are possible with regard to the results of empirical analyses indicating that the impact of a U.S. interest rate shock on Korea's capital flows has decreased since the global financial crisis. The Korean economy has been through numerous transitions since the crisis. Possibly, monetary policies and/or exchange rate policies have changed and play a role, especially after the crisis. Moreover, capital controls or macro-prudential policies have been implemented. Among others, we supplement our main empirical results with a possible answer that hinges on an institutional improvement in financial friction. It is now widely believed that financial friction in international capital transactions plays a very important role in shock propagation, monetary spillover and the resulting volatile capital flows. Especially in emerging economies, binding financial constraints against international capital inflows are crucial to understand external vulnerabilities, especially combined with dollar-denominated debt. Through the lens of the two-country new Keynesian model with financial friction, we claim that the improved pledgeability of net worth can serve a possible answer to the smaller responses of both domestic and foreign investors. That is, if financial friction in capital market is lower than before, the responsiveness of domestic and foreign reallocations of assets with external shocks could now be lower. If the fraction that can be borrowed against the net worth increases due to the increased credibility, the inefficiency during financial intermediation will decrease. Using the mid-scale new Keynesian model in Banerjee, Devereux, and Lombardo (2016), we argue that this hypothesis can qualitatively account for the change in the empirically estimated elasticity of capital inflows.

## II. Literature

Capital flows are the vehicle that enables financial and trade transactions and are the basis for open macroeconomics. Many studies have focused on the determinants of the net capital flows. However, research on gross capital flows, which distinguishes domestic from foreign investors, has received much attention since the

global financial crisis. In a small open economy, especially in an emerging country, an economic crisis often appears as an external crisis; the crisis comes as a tale of foreign capital inflows and subsequent sudden reversals. Accordingly, the emerging country's external crisis is referred to as a sudden capital outflow, or a 'sudden stop'. Researchers have then found that not only foreigners but also domestic investors are actively involved in capital withdraws during contractions. More specifically, while foreigners' inflows turn into abrupt capital stops, at the same time, domestic investors also retrench and pull their external position out actively. This has become a new stylized fact widely believed by many scholars. As the capital inflows and outflows occur at the same time but as the outflows by foreigners usually outweigh the magnitude of inflows by domestic residents, the total net assets are negative (deficits). In this article, we confirm that if there is a shock in the form of an interest rate hike in the United States, foreigners' withdrawals (outflows) and domestic investors' withdrawal (inflows) occur simultaneously in Korea. In particular, these patterns of inflow and outflow have been observed primarily in portfolio flows. On the other hand, regarding FDI and other flows, these patterns are relatively weak.

There have been several important studies of the determinants of gross capital flows. Forbes and Warnock (2012) discussed four types of sudden/extreme capital flows: foreign capital inflows (surges), foreign capital outflows (stops), domestic residents' capital outflows (flights), and domestic residents' capital inflows (retrenchments). The factors that determine each type of capital inflow were explained more by push factors than by pull factors. Specifically, by analyzing quarterly data of 50 countries from 1980 to 2009, it is claimed that the degree of the global risk factor represented by the VIX was the most important factor affecting these rapid flows. On the other hand, Broner *et al.* (2013) emphasized the importance of gross flows along with the procyclicality of the business cycle. Fratzscher (2012) analyzed the determinants of capital outflows using micro data (securities) and argued that capital outflows are determined by external factors such as global liquidity and risk preferences, similar to other studies.

Regarding the capital flows of Korea, Choi (2018) argued that an increase in the Federal Funds rate significantly reduces foreign capital, but not by a large magnitude. Yu (2018) argue that arbitrage factors such as policy interest rate differentials between Korea and the U.S., are important during the pre-crisis period, and risk preferences are more important during the post-crisis period. However, these studies deal only with the behavior of foreigners and do not cover domestic investors, nor incorporate identified shocks. Ours will instead focus on the capital flows of both domestic and foreign investors while using identified U.S. monetary policy shocks. We also focus on how these effects change before and after the global financial crisis.

Close to our study, Yun and Park (2019) reviewed both types of capital flows, as in this paper. They analyzed the impact of policy interest rate differentials between Korea and the U.S. using an autoregressive variance model (ARDL) and the local projection method. They claim that Korea's capital outflow is not systematically related to interest rate differentials prior to the global financial crisis but that it is correlated with residents' other investments and foreign portfolio investments. This has a somewhat different implication from our outcome here. First, we focus on identified interest rate hikes of the U.S. rather than on the simple interest rate difference between Korea and the U.S. Second, we focus on the impact on short-

term fluctuations of capital flows, as we include the time trend as a control variable. Identifying how capital inflows react to simple interest rates may be the first step. However, using the interest rate differential assumes that the elasticity of each country's policy interest rates on capital inflows is identical. That is, they focus on the effects of the variable with the linear and forceful combination of the two interest rates and determine how it is related to capital flows. These may not be linked to our interest or may not be relevant if we assume that the marginal elasticity levels of the interest rate increases in Korea and the U.S. are not alike. Moreover, the simple interest differential is also associated with the endogeneity issue, as the impact of interest rate change expectations on capital outflows could not be controlled. Finally, if we focus on the marginal responses of capital flows with a relatively short-term horizon, the time trend must be included.

To identify a U.S. monetary policy shock, we replicate and update the methodology of Iacoviello and Navarro (2019). After controlling the information given by observable economic variables at the time of the FOMC meeting, we have the portion of the interest rate changes that are not expected by market participants. These will be the series of our U.S. monetary policy shocks. There have been several other attempts, and other identification methods. Most notably, Romer and Romer (2004) collect narrative data available on the day of the FOMC meeting and measure the deviation from the projection based on the narrative data. Gertler and Karadi (2015) use a high-frequency identification method that incorporates the future values of Federal Funds rate. They observe 30-minute-window change of the future of the Federal Funds rate before and after a FOMC meeting. Any changes after the announcement would capture the surprise experienced by market participants and thus would serve as the identified monetary policy shock. However, Romer and Romer (2004) could not estimate the interest rate shock during zero interest rate periods, and we are not able to obtain up-to-date high-frequency data pertaining to Federal Funds futures. Instead, Iacoviello and Navarro (2019) provide an intuitive but simple method by which to replicate and extend the series.<sup>5</sup>

Whether to control the time trend when estimating the impulse responses of capital flows is also important. As can be seen in Yun and Park (2019) and Yun (2018), interest rate differentials and capital outflows have been on the rise since 2012. There is no consensus among researchers as to whether this trend indicates a causal relationship. Yun and Park (2019) claim this trend to be important and possibly causal. However, it may also be that the trend shows the long-term trend of financial globalization. Our empirical results present a different perspective on the behavior of capital flows, with different policy implications.

When studying the determinants and behaviors of capital flows, some researchers emphasize the importance of global risk factors, particularly the VIX, an indicator of the volatility expectations of the U.S. stock market that is indicated in the Chicago futures options market. Kang, Kim, Suh, and Kang (2018) also emphasize that the global factor represented by the VIX is one of the most important causes of capital

<sup>5</sup>In Iacoviello and Navarro (2019), the authors examine the impact of U.S. interest rate shocks on GDP in developed and emerging economies. Utilizing a panel local projection approach with a vulnerability index, they conclude that U.S. interest rate shocks are negatively transmitted to neighboring countries but that the degree of spillover depends on a certain vulnerability index, such as the exchange rate system, degree of trade openness, or other instability indicators.

inflows in emerging countries. However, as argued in Miranda-Agrippino and Rey (2020), the VIX could be an endogenous variable that reacts to U.S. monetary policy and that two variables are thus closely correlated. We assess specifications with or without the VIX as a control, though the results were found not to vary much. Bruno and Shin (2015) also argued that the tightening monetary policy of the U.S. led to a decrease in capital outflows through banks' risk-preferred channels.

The following studies explore how U.S. monetary policy is transmitted internationally. Dedola, Rivolta, and Stracca (2017) use Romer and Romer (2004) to identify monetary policy shocks in the United States and then to assess the impact of these shocks on macro and financial variables in a sample of 36 countries. After analyzing the impact of U.S. interest rate shocks on individual countries through the Bayesian structural VAR approach, each country's impulse response is estimated, after which the weighted average response of all countries is estimated. The analysis shows that the impact of an interest rate hike in the United States has a negative impact on individual countries' production and employment levels. Albrizio, Choi, Furceri, and Yoon (2019) empirically examined the impact of U.S. interest rate shocks on bank flows and claim that U.S. interest rates led to a decrease in bank capital outflows.

Unlike other studies, Banerjee, Devereux, and Lombardo (2016) present how the monetary policies of the core and periphery should be coordinated under external shocks in a two-country New Keynesian model with financial friction. The authors show that the shock spillover is weaker under the optimal monetary policy if the both core and peripheral countries collaborate as compared to that under a Taylor rule type of monetary policy. Along with a theoretical model, Banerjee, Devereux, and Lombardo (2016) provide an empirical analysis of gross capital flows. We use a version of the model presented in Banerjee, Devereux, and Lombardo (2016). We change the parameter values of the model, which governs the fraction of the net worth that can be funded, to determine how the impulse response pattern changes.<sup>6</sup>

The remainder of this paper proceeds as follows. In chapter 3, we construct the series of identified U.S. monetary policies, the data, and then present the empirical specifications. Chapter 4 provides our main empirical results, which constitute the main contributions of the paper. We discuss the results and outcomes in light of earlier findings. Lastly, in chapter 5, we seek a possible cause of the change of the elasticity before and after the crisis. We use the framework of Banerjee, Devereux, and Lombardo (2016) and assess how much the improvement in the degree of financial friction can explain our empirical results. Chapter 6 concludes the paper.

### **III. Data and the Econometric Methodology**

#### *A. U.S. Monetary Policy Shock*

This section presents the methodology of Iacoviello and Navarro (2019) to identify a U.S. monetary policy shock. The United States is the most important capital exporter and thus the global financial center. In particular, considering the

<sup>6</sup>We note that Devereux, Engel and Lombardo (2020) also use a version of the model in Banerjee, Devereux, and Lombardo (2016) to derive an implementable monetary policy.

impact on Korea, interest rate shocks derived from U.S. monetary policy will be one of the most important external factors affecting Korea. Accordingly, this analysis attempts to estimate the impact of U.S. interest rate hikes.

Various factors affect the monetary policy stance of the U.S. Directly incorporating the Federal Funds rate would bias our estimation, as the expected interest rate change can affect capital flows even before the actual changes. Therefore, it is necessary to control the information held by market participants at the time of the monetary policy. When the interest rate changes in the market, economic actors will act proactively, and this tendency becomes more pronounced in capital flows. For example, at the time the United States ended the zero-interest era and normalized her monetary policy, the actual rate hike took place in 2016, but because such normalization had been widely predicted before this event, U.S. Treasury bond yields began to rise starting at the end of 2015. Thus, subsequent capital reversals took place around the end of 2015. The actual increase in the interest rate due to the increase or decrease in the interest rate will be correlated with capital outflows before the actual increases in December of 2016. Several existing methods can be used to identify U.S. interest rate shocks, but this paper uses the relatively simple form of identification used by Iacoviello and Navarro (2019).<sup>7</sup> It is straightforward, but we believe that it is very intuitive at the same time and that it is rigorous enough to identify monetary policy shocks. The following regression equation is utilized to identify the impact of interest rate hikes in the United States.

$$r_t = \theta_0 + \theta_1 \sum_{p=0}^4 Z_{t-p_t} + u_t$$

Here,  $r_t$  is the U.S. Federal Funds rate,  $Z_t$  denotes the control variables including current inflation rate and the log of the real GDP and corporate spreads in the U.S. We also include lagged values of the U.S. Federal Funds rate, the time trend and squared terms of the time trend. We use lagged variables of the last four quarters. Our series stretches from the third quarter of 1987, when Alan Greenspan was appointed as chairman of the Federal Reserve Board, to the most recent first quarter of 2019. It should be noted that in our main regression, our sample starts in 1995 due to data availability pertaining to the international investment positions of Korea. The shadow rate of Wu and Xia (2016) replaces the Federal Funds rate in the era of zero interest rates.

Figure 1 shows the U.S. monetary policy shocks identified through the regression equation. We find that the Federal Funds rate and the identified shocks can vary substantially depending on the period. In particular, starting in 2002, there is a stark difference between the two series.<sup>8</sup> Ultimately, the series replicate and update the U.S. monetary policy shock of Iacoviello and Navarro (2019) up to the first quarter of 2019.

<sup>7</sup>Iacoviello and Navarro (2019) provide a simple but intuitive methodology with which to identify monetary policy shocks. We also have attempted high-frequency identification using Federal Funds futures. However, the necessary data is only available for very recent periods.

<sup>8</sup>A shock in the form of a significant spike in the US interest rate is observed in the first quarter of 2009, while this is not seen in changes in simple interest rates. We note that in our baseline regression, we exclude the sample period of 2009, which contains extreme U.S. interest rate shock increases. This does not alter our main results.



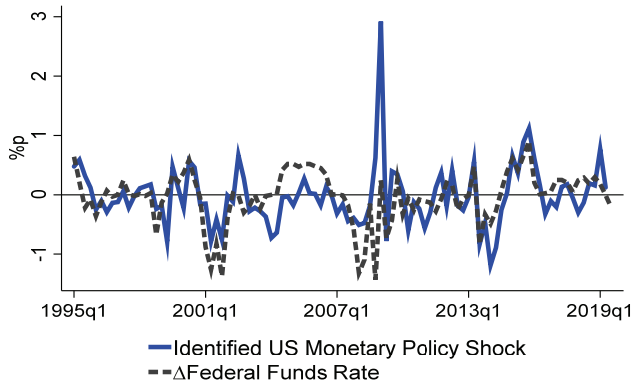


FIGURE 1. IDENTIFIED U.S. MONETARY POLICY SHOCKS

*Note:* The solid line represents identified U.S. monetary policy shocks, and dashed line indicates changes in the Federal Funds rate. We identify U.S. monetary policy shocks by projecting the Federal Funds rate onto the information set of current and lagged macroeconomic variables, as in Iacoviello and Navarro (2019).

### B. Data and the Econometric Methodology

The local projection method, initially proposed by Jordà (2005), has been used in various impulse-response analyses. The method does not require the specification of the structural relationships between variables in a dynamic system. Thus, it is known to have more flexibility and greater versatility than other methods that estimate systems of autoregressive variables, i.e., VARs. Accordingly, it has been very popular in recent years and has been applied especially when incorporating state dependencies. While it is popular due to its versatility, it also has shortcomings in that the number of samples decreases rapidly as the spanning of the impulse response increases. Thus, it can drop observations in a relatively short spanned sample.

Here, we consider the following regression equation,

$$y_{t+h} - y_{t-1} = \alpha^h + \beta^h MS_t + \gamma^h \sum_{p=0}^2 W_{t-p} + u_{t+h},$$

where  $y_t$  is the log stock of assets or liabilities,  $MS_t$  is the identified U.S. monetary policy shock as described in the previous section, and  $W_t$  denotes the added control variables. The capital stock  $y_t$  distinguishes foreign liabilities from residents' assets and is further categorized into direct investments (FDI), portfolio investments, and other investments, as in financial accounts in the balance of payment process.

We note that the specification and selection of controls proceed similarly to Banerjee, Devereux, and Lombardo (2016). Control variables include current and lagged (up to two quarters) values of the real GDP growth rate, nominal exchange rate appreciation, real GDP growth rates of major trading partners, interest rate changes of one-year monetary stabilizing bonds, and percentage increase of foreign exchange reserves. The real GDP growth would capture the capital flows generated by

additional production. Additionally, the domestic interest rate and nominal exchange rate fluctuation would capture exogenous variations in the yield may affect capital flows. The time trend and the dummy for the crisis periods are included as further controls.<sup>9</sup> We presume that capital inflows by one type do not have any structural correlation with another. In other words, the regression equation of a certain type of capital flow does not have other types of capital flows as control variables.

In the above regression equation,  $\beta^h$  is the elasticity of the  $h$ -period-ahead capital adjustment to a U.S. monetary policy shock. In a standard VAR, historical evolution and the consequent inference can be made by estimating a system of autoregressive variables. However, when doing so, the estimated coefficients of the model are not easily understood nor useful if one is interested in impulse and response factors. Instead, in local projections, the effect of the independent variable on the dependent variable is estimated by locally projecting the former onto the latter. It does not require specification of the true multivariate dynamic system. Thus,  $\beta^h$  in our regression equation would convey a more intuitive interpretation of the system in terms of the impulse response coefficients. Indeed, Plagborg-Møller and Wolf (2020) argue that VARs and local projections will ultimately provide the same estimate if the data-generating functions are identical. That is, VAR ( $\infty$ ) and local projection would give an identical coefficient and confidence interval asymptotically.

In Figure 2, we plot the evolution of logged external assets and liabilities. Again, the international investment position data is only available after 1995, and our data extends from 1995q1 to 2019q3. We also note that mid-90s is the period of the beginning of financial liberalization. Starting in 1989, restrictions on external capital accounts slowly began to be released. Thus, it will be more appropriate to cut the periods before 1995 and focus only on the periods afterwards.

The upper left part of Figure 2 shows that external assets and liabilities increased quite dramatically before the global financial crisis. However, the pace of the growth slowed somewhat after the crisis for the foreign liabilities. Instead, external assets held by residents grow more rapidly. External assets swelled more compared to external liabilities by 2014q3, and Korea became a net external creditor after that point. From the figure, we can observe the importance of gross capital flows. It is increasingly important to understand the determinants of both the behaviors of residents and of international investors.

We can also confirm that both the FDI and other assets catch up with the external liability amount. FDI assets surpass this amount even before the global financial crisis. While the magnitude of portfolio assets is slightly smaller than that of the liabilities, the discrepancy between two is also narrowed dramatically. Again, in the regression equation, the dependent variable  $y_{t+h} - y_{t-1}$  captures the difference between the  $h$ -period-ahead values of the log assets or liabilities and the values at  $t - 1$ . Additionally, the local projection method estimates the average dynamic responsiveness of the monetary policy on those distanced variables. The estimated coefficients can be interpreted as the monetary policy responses of external assets or liabilities.

<sup>9</sup>The crisis dummy is one for 2008q1-2009q2 and 1997q4-1998q1. Here, we split the sample before and after the crisis, dropping the period of 2009 from our entire analysis in our baseline specification.

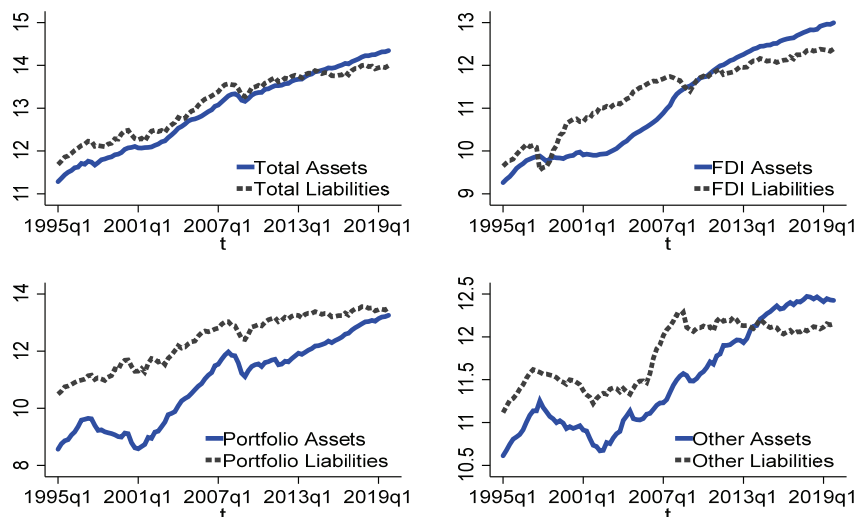


FIGURE 2. EXTERNAL ASSETS AND LIABILITIES OF KOREA

*Note:* The solid line indicates the log of external asset holdings by residents. The dashed line represents the log of the foreign liabilities of foreign investors.

Thus far, we have examined the stock of external assets and liabilities. In Figure 3, we instead plot the first differenced values of the log external assets and liabilities. Thus, these percentage changes of the stock of assets or liabilities map into capital flows of different types of assets or liabilities. We note the following: first, the capital flows of residents and international investors are highly correlated. The similarities between the two series are more pronounced in the portfolio flows than in the FDI.

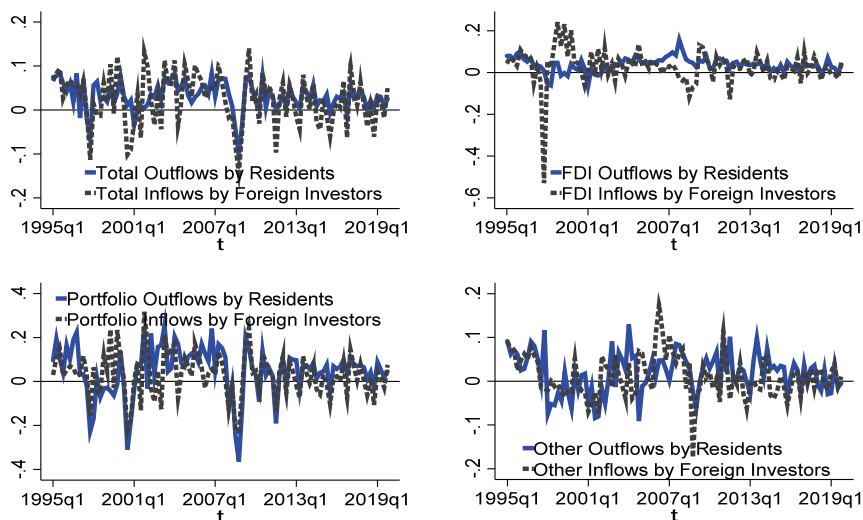


FIGURE 3. CAPITAL FLOWS (CHANGES OF EXTERNAL ASSETS AND LIABILITIES) OF KOREA

*Note:* The solid line indicates the log differences of external asset holdings by residents. The dashed line denotes the log differences of the foreign liabilities of foreign investors.

Second, the volatility of portfolio flows is greatest, while the volatility levels of FDI and other flows are less significant. Third, the overall volatility of capital flows is slightly subdued after the global financial crisis, but not by much. From the first two arguments, we can expect the impulse response of flows by residents and international investors to be alike, as in other studies of small open economies. In next section, we show that the impulse responses of total gross capital flows are mostly driven by portfolio flows. It is also important to note that the overall volatility does not decrease notably after the global financial crisis. Thus, any significant change in the elasticity of a U.S. monetary policy shock will be surprising.

## IV. Empirical Results

### A. Main Results

In this chapter we present our main empirical results. We split our sample periods into two sub-samples and run an impulse response analysis independently for each bin. We split our samples for the following reasons. With a U.S. monetary policy shock, we want to observe the gross withdrawals of capital flows in Korea, which are observed in many other countries. That is, we examine whether there are inflows by residents and outflows by foreigners along with a U.S. monetary policy shock. We report the results after running a regression on the entire sample in Appendix A. However, we could not recover the withdrawals of capital reported in other studies for the entire sample.

At the same time, we examine a possible structural break in the data-generating processes in different time periods. The inclusion of the great financial crisis periods could also deteriorate the overall results due to extreme capital flows or monetary policy shocks during these periods.<sup>10</sup> Thus, in our baseline regression, we split our sample and presume that each sample period follows different data-generating processes and impulse responses.

Figure 4 shows the impulse responses to U.S. monetary policy shocks for domestic residents' capital flows before the global financial crisis. As in Albrizio *et al.* (2019), we report 68 percent and 90 percent confidence bands; the dark band denotes the 68 percent band and the light band is the 90 percent error band.

At the moment of a 100-basis-point U.S. monetary policy shock, the total amount of external assets by residents dropped by around 1.7 percent (of its previous stock). On average, there are small capital withdrawals by residents. The inflows last for two quarters, reaching 4.8 percent, and slowly return to the initial level afterwards. The magnitudes of capital inflows by residents are not statistically significant at the 90% confidence interval at the peak. Again, we will compare our results with foreign investors' impulse responses to determine whether the magnitude is larger in the responses of the stops, as in other countries.

The results vary if we focus more closely on the different types of capital flow by residents. Portfolio flows are most responsive to U.S. monetary policy shocks. When

<sup>10</sup>We note that in the companion paper of Choi (2020), the baseline regression includes the entire sample.

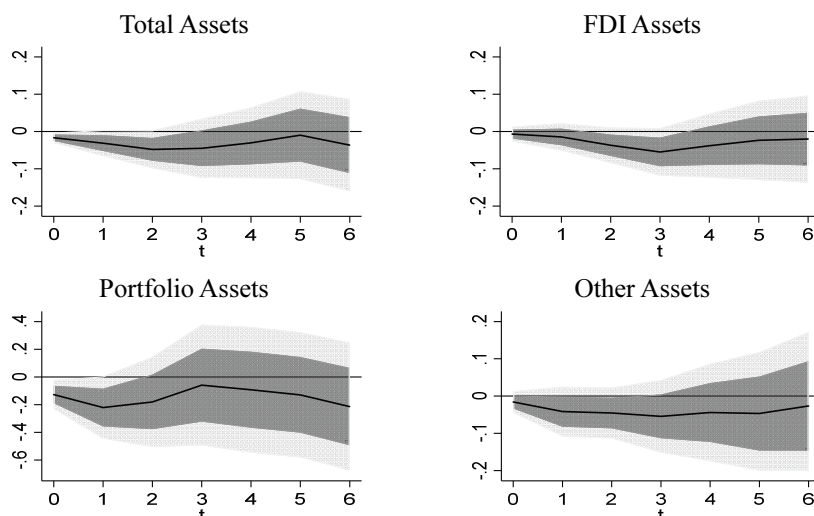


FIGURE 4. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS FOR ASSETS BEFORE THE GLOBAL FINANCIAL CRISIS

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks for the logged assets of residents. The sample ranges from 1995q1 to 2008q4. Light grey denotes the 90 percent confidence interval, while dark grey is the 68 percent confidence interval.

hit by a 100-basis-point shock, there are withdrawals by residents. Portfolio investments drop by 12.7 percent at that moment and further by 22.1 percent during the subsequent first quarter. Portfolio inflows are reversed in the second quarter and slowly rebound. For other flows, including banking flows, there are also capital inflows by residents. The magnitude amounts to 5.4 percent the third quarter after the shock. FDI flows also witness inflows of residents, but in a greatly delayed pattern. In summary, capital flows by residents are most notable in portfolio flows. While the magnitude and statistical significance are not very strong in the flows overall, those of the portfolio flows stand out noticeably.

Next we move on to the impulse responses of foreign investors. Figure 5 shows the results of the impulse responses to a U.S. monetary policy shock on capital flows by foreign investors before the global financial crisis. When hit by a 100-basis-point increase in U.S. monetary policy, foreign investors pull out their capital by around 6.0 percent (relative to its previous level). The capital outflows or withdrawals by foreign investors continue for up to two more quarters, and the magnitude amounts to 13.8 percent. The overall impulse is greater compared to the average withdrawal amount by domestic residents. Thus, we will observe net capital outflows on average when hit by an external U.S. monetary policy shock. The results are consistent with the standard narratives pertaining to average emerging economies.

Again, when further distinguishing between the types of flows, we find that the response is strongest for portfolio flows. The bottom left part of Figure 5 shows that with a one-hundred-basis-point increase in the U.S. monetary policy, portfolio outflows by foreign investors would reach 13.4 percent. The outflows amount to 28.9 percent after two quarters, after which they reverse. The response by the FDI flows also marks its lowest point during the second quarter, while the magnitude is not as strong compared to the portfolio flows. However, the responses of other flows, which

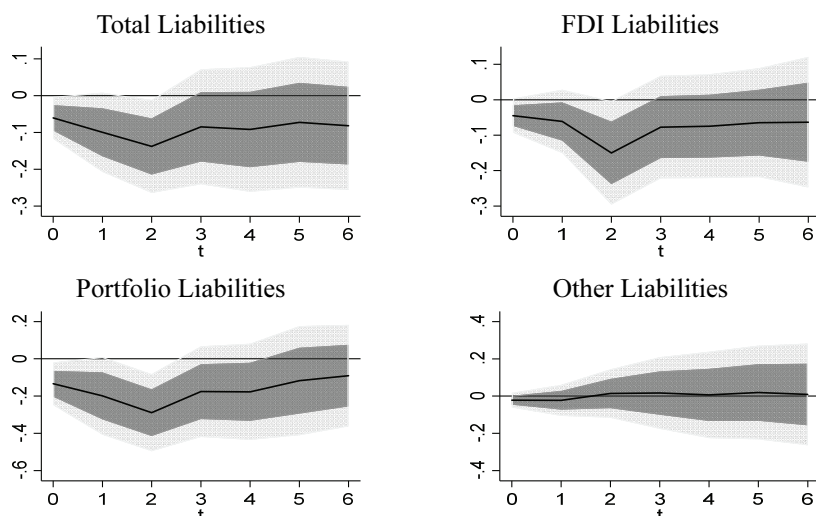


FIGURE 5. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS ON LIABILITIES BEFORE THE GLOBAL FINANCIAL CRISIS

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks for logged liabilities, i.e., the claims of foreign investors. The sample ranges from 1995q1 to 2008q4. Light grey indicates the 90 percent confidence interval, while dark grey shows the 68 percent confidence interval.

include banking flows, are not very notable.<sup>11</sup>

Next, we move on to the after-the-crisis subsample periods. As explained previously, many people argue that capital flows in Korea became more resilient. In Figure 6, we report the impulse responses to a U.S. monetary policy shock for residents' assets. Again, there are contractions in total assets, and the pattern is driven by portfolio flows. In upper left part of the figure, we can observe that with a one-hundred-basis-point increase in the U.S. monetary policy, total assets would drop by 1.9 percent. The magnitude reaches 2.9 percent during the subsequent third quarter.

While the inflows are similar at the moment of the shock, subsequent flows are much smaller than they were before. In portfolio flows, the inflows amount to 9.9 percent during the third quarter after the shock. We note that the scale on the y axis is much large for portfolio flows than for any of the other flows. We claim that the overall pattern is again driven by portfolio flows, but at a much lower magnitude than in the before-the-crisis period.

Moving forward to the foreign investor's side in Figure 7, we also do not see any significant contractions in the total claims with those beforehand. At the moment of a 100-basis-point U.S. monetary policy shock, overall claims by foreign investors decrease by 4.4 percent. They drop further by as much as 4.8 percent and then rebound afterward. However, this outcome is not statistically significant at the 90 percent confidence level. In agreement with all other analyses, portfolio flows are the main drivers of the overall flows by foreign investors. However, the magnitude

<sup>11</sup>On average, banking flows are said to have the most responsive results when hit by an external shock. Albrizio *et al.* (2019), which covers banking flows, reports around a 12 percent decrease in the second quarter. Also, Choi (2020) reports the most responsive results in banking flows. Unlike those studies, in our baseline specification, we did not observe any significant results in other flows.

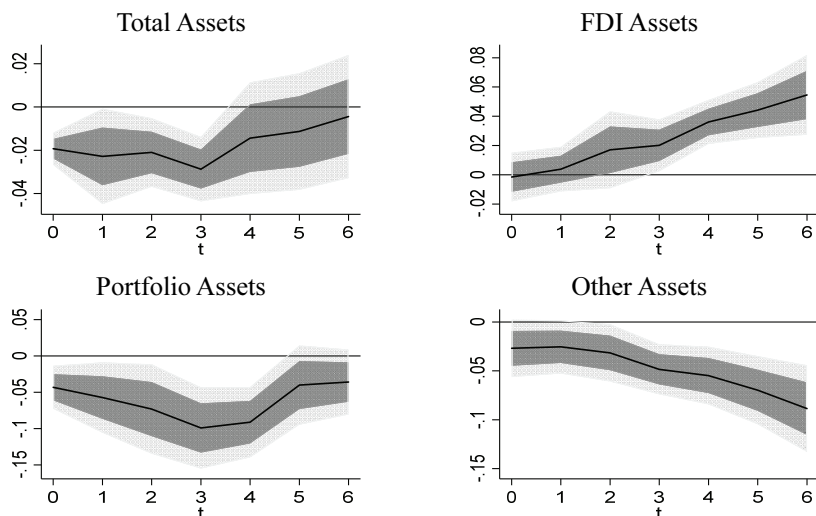


FIGURE 6. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS FOR ASSETS AFTER THE GLOBAL FINANCIAL CRISIS

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks for the logged assets of residents. The sample ranges from 2010q1 to 2019q2. Light grey shows the 90 percent confidence interval, while dark grey shows the 68 percent confidence interval.

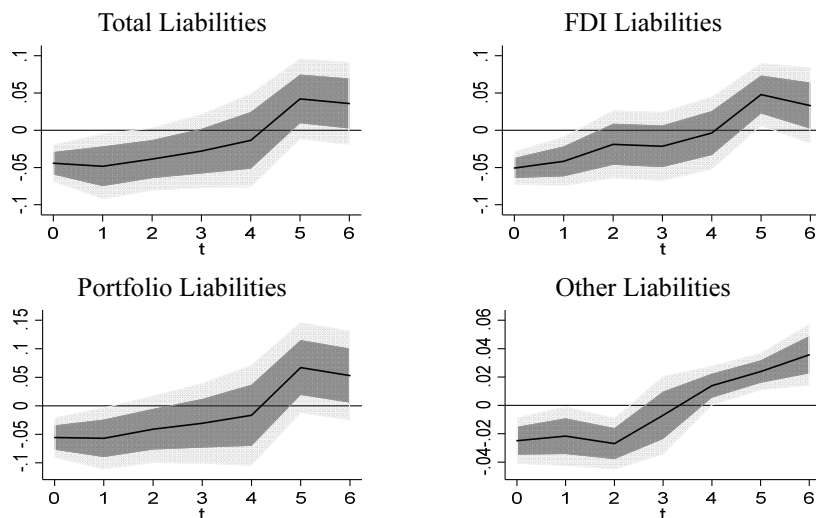


FIGURE 7. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS ON LIABILITIES AFTER THE GLOBAL FINANCIAL CRISIS

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks for logged liabilities, i.e., the claims of foreign investors. The sample ranges from 2010q1 to 2019q2. Light grey indicates the 90 percent confidence interval, while dark grey shows the 68 percent confidence interval.

of withdrawal at the moment of the U.S. monetary policy shock is 5.6 percent, and then 5.7 percent in the following quarter. Compared to 13.4 percent and 19.9 percent, the magnitudes are much smaller. For FDI and other flows by foreign investors, there are not statistically significant responses at the moment of a U.S. monetary policy

shock. Other flows show slight increases after six quarters, but again the results are not statistically significant at the 90 percent confidence level.

At this stage, let us compare the impulse responses of the two different sample periods together. In Figures 8 and 9, we combine all of the figures presented earlier. We note that the dashed line here indicates the results for the before-the-crisis sample, while the solid blue line represents the after-the-crisis sample. In Figure 8, we find that retrenchments in assets are notable, especially with regard to portfolio assets before the crisis. However, the results are not preserved in the after-the-crisis period. Again, it is difficult to claim that patterns by domestic investors show any withdrawal of assets overall upon a U.S. monetary policy shock. For portfolio assets, a main component of capital flows reacting to U.S. monetary policy, we can observe some degree of inflow by residents. Nonetheless, the magnitude compared to the before-the-Crisis period are again less than half. We find that the overall responsiveness is dwarfed after the crisis.

Figure 9 shows that the magnitude of withdrawals by foreign investors is also less than half that in after-the-crisis sample. While the level of foreign claims does not recover to the initial level after six quarters in the before-the-crisis sample, the blue line returns to the initial level relatively quickly. These results are mostly driven by portfolio flows. We note that the scales of the figure for portfolio flows are twice as large as that of the overall figure. While there is more than a 28 percent decrease in portfolio flows in the before-the-crisis sample, those in the after-the-crisis sample do not exceed six percent throughout. We also note that the 90 percent error band of the impulse response in the after-the-crisis sample does not overlap with the impulse response of the before-the-crisis sample.

We note that the figures overlay the results of the two different samples. Thus, one cannot draw any statistical inferences based on our results. Our results are on average consistent with the prior hypothesis that the responsiveness of capital flows due to a shock is weaker in the after-the-crisis period. As we do assume that each period follows a different data-generating process with different coefficients for all other controls, statistical inferences or tests could not be realized from the figures. We also add a couple of robustness checks in the appendix, including a specification incorporating the VIX or a different time trend. These results are broadly consistent with our baseline results.

Lastly, we compare the results between the current article and the results in Choi (2020). In a companion paper, Choi (2020) documents the effects of the U.S. monetary policy on gross capital flows, an analysis similar to ours. While asking the same question, current article uses the log stock of assets and liabilities, but Choi (2020) uses capital flows normalized by quarterly GDP. Also, current one focuses on the dynamic ( $h$ -periods apart) log changes of assets and liabilities. However, the specification in the companion article uses the spontaneous flows (capital flows normalized by the quarterly GDP) as the dependent variables. The different types of normalization and the different specifications yield somewhat different results. First, though Choi (2020) also finds marginally decreased elasticity of capital flows after the crisis, the results are mainly driven by other flows, which include banking flows. Indeed, with the different normalization process, overall volatilities are greater in the other flows and the marginal elasticity of the flows to a U.S. monetary policy shock is larger than in the portfolio flows. It is not possible to claim that one



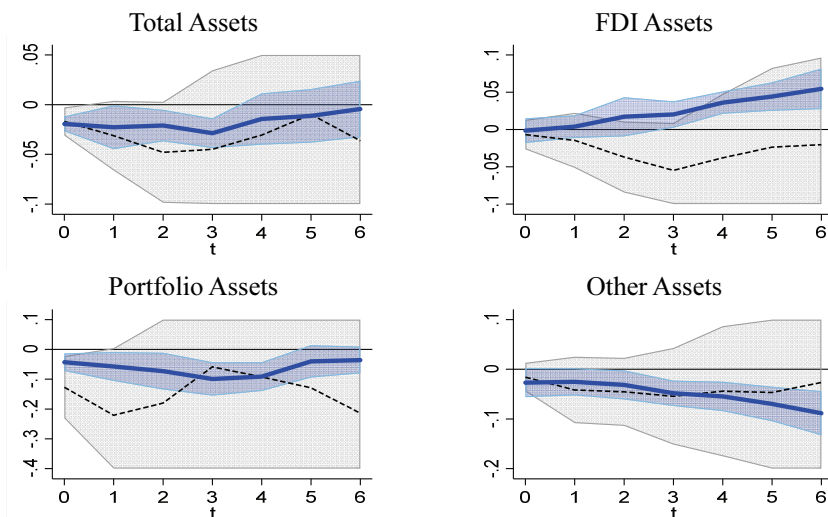


FIGURE 8. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS FOR ASSETS BEFORE AND AFTER THE GLOBAL FINANCIAL CRISIS

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks for the logged assets of residents. The solid blue line indicates the results from the after-the-crisis period (2010q1–2019q2), and dashed line denotes the results from the before-the-crisis period (1995q1–2008q4). Here, the 90 percent confidence intervals are reported.

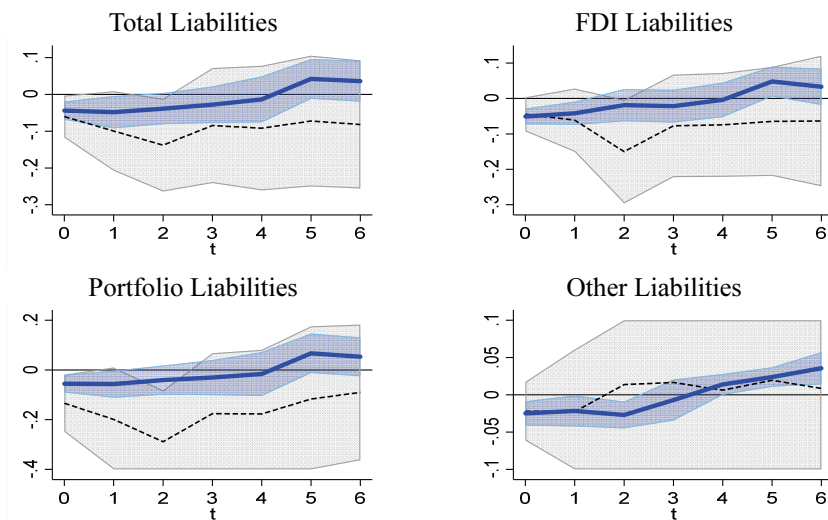


FIGURE 9. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS ON LIABILITIES BEFORE AND AFTER THE GLOBAL FINANCIAL CRISIS

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks for the logged assets of residents. The solid blue line indicates the results from the after-the-crisis period (2010q1–2019q2), and dashed line denotes the results from the before-the-crisis period (1995q1–2008q4). Here, the 90 percent confidence intervals are reported.

specification outperforms the other. A different normalization method implies a different anchor by which to measure the percent or the percentage change of capital stock. The current article uses the percent change compared to its own level of stock, while the previous article uses the percentage change over the GDP level as the basis

for the analysis.

Thus, our baseline results and consequent claims possibly depend on the specification used. Indeed, the lack of robustness in the impulse response analysis of a monetary policy shock is well known and widely debated.<sup>12</sup> Although we confirm our main message in our baseline regression results, we admit that our results may vary if we apply another specification, e.g., the number of lags included, other controls, etc. Choi (2020) also document an extensive robustness analysis, concluding that the results may vary if a different specification is used or if including other control variables.

## V. Financial Friction and the Elasticity of Capital Flows

Thus far, we have empirically analyzed the impact of U.S. monetary policy shocks on capital flows in Korea. In particular, we confirmed that in our baseline regression, the marginal responses of capital flows have been far less notable in the sample periods after the global financial crisis. In this section, we seek possible explanations for the previous empirical results.

We conjecture that if financial friction, which has been claimed as the main source of external vulnerability and the consequent volatile capital flows, can be improved, the responsiveness could decrease. Korea has passed through various macroeconomic transitions after the global financial crisis. As shown in Figure 2 and Figure 3, the accumulation of assets has outpaced liabilities. Since 2014q3, external assets held by residents do exceed claims by international investors. Among others, we focus on institutional changes in financial friction. We examine the theoretical model and determine whether these improvements of financial friction may be replicated in the empirical results in the previous section; if the fraction of net worth that can be pledged is increased when the Korean financial sector borrows from outside, it should follow that the elasticity of the outflow decreases.

### A. A Two-Country New Keynesian Model with Financial Friction

Banerjee, Devereux, and Lombardo (2016) construct a two-country new Keynesian model (center (core) and the periphery) with financial friction. They focus on the derivation of optimal monetary policies with international cooperative stances. However, a basic model was applied in other studies, such as Devereux, Engel and Lombardo (2020), who derive implementable monetary policy rules, for instance. Here, we do not focus on any changes in monetary policy, nor on whether it became cooperative or not after the global financial crisis. Instead, we utilize the simplest form of monetary policy, Taylor rules, in their model, and vary the degree of financial friction that governs leverage constraints.

Because we use the same model used as in Banerjee, Devereux, and Lombardo (2016) and Devereux, Engel, and Lombard (2020), we abstract from the details of the model.<sup>13</sup> We also note that as in the original paper, we abstract from quantitative

<sup>12</sup>See Ramey (2016) for a detailed debate.

<sup>13</sup>We provided the equilibrium equations that are used for the simulations in the Appendix.

exercises. The model's intuition is as follows. In the model, there are two countries; the core and the periphery. Central banks in each country operate their respective monetary policies according to the Taylor rule, and there is Calvo-type price rigidity. The core households will issue a one-period risk-free bond, and the households of the periphery will attempt intertemporal consumption-smoothing through bonds issued by the core households. Companies in each country combine labor and capital to produce core and peripheral products, respectively. Households in each country will consume final goods that combine consumer goods from their own and other countries. These are the assumptions of a standard two-country model.

In addition, we also assume the following types of financial friction. Instead of a household owning capital and lending it directly to firms, a bank exists as an intermediate.<sup>14</sup> Banks have equity capital and can additionally borrow, but only a certain fraction of their net worth. Thus, there is a leverage constraint. The core bank borrows from the core household considering their net worth, purchase capital goods and loan those to the firms in the core country. In addition, the core bank also loans a fraction of its funds to banks of the peripheral countries. Periphery banks borrow capital from the core banks, along with their own capital. They then purchase capital goods and rent those to firms in the periphery. For convenience, we assume that a bank in the periphery does not receive any funds from its own households. In this structure, the households of the periphery hold bonds from the core households. The core households receive funds by issuing assets to periphery households and then rent those to the core banks, who will finance the banks in the periphery and firms in the periphery eventually. With this system, we can determine the *gross* capital flows between the two countries.

The model with financial friction in the banking sector has the following discrepancies compared to the standard model. If there is a monetary policy shock in the core economy, the leverage constraints in the bank will be tightened and the spread between the interest rate for funds borrowed by the company and the interest rate of the risk-free bond will increase. As a result, capital is not sufficiently brokered and is not sufficiently transferred to production. In addition, as the amount of funded capital decreases, core investors reduce their amounts of capital invested in peripheral countries. In other words, foreign claims will decrease with monetary policy shock. The impact of this increase in core interest rates leads to a decrease in the income of the peripheral households due to the general equilibrium effect. The peripheral households sell foreign assets, and the periphery residents' capital invested abroad then decreases.

Regarding the impact of a US rate hike, the model creates inefficiency in financial intermediation, and such factors are greatly amplified by the impact of capital inflows. From a resident's point of view, leverage constraints and an increase in spreads are the most important causes of volatility in capital outflows. In the model, the parameters of these leverage constraints are denoted by  $\kappa_i$ . In the original paper, the stochastic processes  $\kappa_i$  of the two countries are identical. On the other hand, in this paper, we assume that each country has processes with different mean value

<sup>14</sup>We note that banks in the model do not necessarily stand for banking flows. Rather they represent any kind of financial intermediaries that intermediate capital between agents.

parameters. Thus, our presumptions during these thought experiments are as follows: during the period before the global financial crisis, Korea, i.e., the periphery, has a smaller value than a developed country. However, after the global financial crisis, there is an improvement in the credibility of Korean borrowers, and fractions of net worth that can be pledged are enhanced.  $\kappa_t^e$  increases and the degree to which leverage is restricted is lowered.

At this point, we examine the responses of periphery household's assets and core household's assets (liabilities of the periphery) upon a core rate hike. The leverage constraints of core banks have a value of 0.45 both before and after the global financial crisis. Core banks can borrow 45% of their equity value from households. However, the leverage constraint of peripheral banks has a value of 0.38 before the global financial crisis and is then enhanced to 0.45 thereafter. Periphery banks can borrow 38% of the value of capital from core banks beforehand. These restrictions will be increased to 45% after the global financial crisis due to the institutional improvement. If the inefficiency of financial intermediation is reduced, the impact of the interest rate hike on the core will also be lower.

With an enhanced value of  $\kappa_t$ , the core monetary policy hike will not be transmitted to periphery economies as much as before. As a result, loans from core banks to peripherals decrease by less. The income decrease by periphery households due to the interruption in financial intermediation would also be less severe. The assets that the peripheral households withdraw from the core households will be smaller as a result.

The results of these simulations are reported in Figure 10. The Y axis represents the deviations from the steady-state values. We find that the impact of a rate hike in the core country (U.S.) reduces foreign assets in both countries. However, there are discrepancies between different values of  $\kappa_t^e$ s. The solid blue line shows the impulse responses with an increase in  $\kappa_t^e$ , while the dashed line shows the impulse responses with the previous value of  $\kappa_t^e$ . Again, a larger  $\kappa_t^e$  indicates an improvement in institutional friction and thus applies to after-the-crisis periods. We

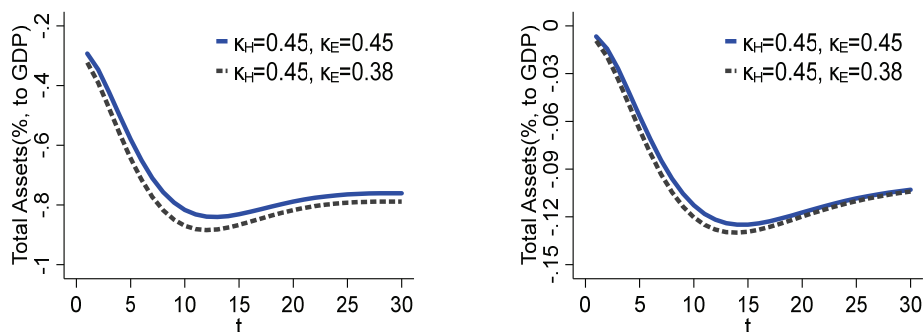


FIGURE 10. IMPULSE RESPONSES TO A MONETARY POLICY SHOCK IN A CENTER COUNTRY PERIPHERY

*Note:* The figure shows the external positions of the periphery and the center economies relative to each other. Total assets of the center will be a liability to Korea. The blue line denotes the impulse response of a center monetary policy shock with increased leverage constraints.

also find that for the blue solid line, there is less deviation from the steady state due to the impact as compared to that indicated by the black dashed line. That is, there is less responsiveness in the reallocation of assets than beforehand. With the improvement in foreign investor's credibility and the improved pledgeability for the given value of net worth, spillover from the U.S. monetary policy becomes weaker.

### *B. Other Possible Answers, International Trilemma and Independence of Monetary Policy*

To this point, we find that institutional changes in financial intermediations may explain the lower level of responsiveness of capital flows to a U.S. monetary policy shock. However, there could also be many other culprits.

Along with various macroeconomic transitions, it is possible that in different circumstances, policies which govern the responsiveness of capital flows to U.S. monetary policy shocks have changed. Currently, there are many studies documenting optimal monetary policy responses to foreign capital inflows. An optimal monetary policy which simultaneously determines the optimal exchange rate policy depends on domestic fundamentals, such as dominant currency pricing and financial friction.<sup>15</sup> With the altered external circumstances, monetary policy may have changed as well. At the same time, macro-prudential policies or capital controls have been adopted since the global financial crisis, and those may have been effective since that time.

Indeed, Korea may not be the only country that has undergone a transition with regard to international capital flows. Shin (2014) claims that while the first phase of global liquidity was marked by banking flows, the second phase of global liquidity after the global financial crisis is now marked by bond flows, especially debt securities. Possibly, it is more of what is termed push-side transitions than their push-side counterparts. Avdjiev *et al.* (2020) noted that the overall marginal response of capital flows based on U.S. monetary policy rose substantially due to the 2013 Fed's 'taper tantrum', and then reverted. They claim that the change in the responsiveness was mainly driven by increases in the lending shares of more capitalized banking systems. Forbes and Warnock (2020) claim that extreme capital flow movements themselves have not increased since the global financial crisis. At the same time, extreme capital flow movements are less correlated with changes in global risks.

Even if we are not sure of the true cause of the change in vulnerability of capital flows, we can discuss possible influences on monetary policy, especially the independence of monetary policy. One of the most cited propositions in international economics is the international impossible trinity. The trilemma argues that the opening of the capital market, the independence of monetary policy, and a fixed exchange rate cannot be achieved simultaneously. A small open economy which operates a fixed exchange rate system and has a high degree of openness in the capital market has significant limitations in terms of monetary policy operations.

Market participants are empirically testifying that Korea's capital outflows are strong against external shocks. Reflecting this situation, the IMF's Article IV report evaluated Korea's financial assets as safe assets according to such a situation. If this

<sup>15</sup>See Akinci and Queralto (2019) and the references therein.

change in the trend is true, it will be possible to secure considerable independence of monetary policy operations. It is possible to focus more on internal problems during the operation of monetary policy. Further discussions and research are needed to determine whether this resilience actually exists.

## VI. Conclusion

In this article, we document the effects of U.S. monetary policy shocks on gross capital flows in Korea. External shocks are typically the main sources of vulnerability in an open economy. Especially in Korea, several waves of capital inflows and subsequent sudden withdrawals have caused severe fluctuations. To understand the effects of U.S. monetary policy shocks, which are claimed to have caused the global financial crisis, not only foreign capital flows but also residents' capital flows should be the lynchpin of monetary and fiscal policies.

We show that first in Korea, as in other small open economies, not only *net* but also *gross* capital flows matter. When U.S. monetary policy shocks increase, foreign and domestic investors withdraw their positions in Korea and in other parts of the world, respectively. Consistent with people's prior behavior, the elasticity of capital flows have changed since the global financial crisis. We explore the possibility of an institutional improvement on financial friction. If the amount to pledge against foreign investors has increased, the responses of both types of investors would decrease upon a monetary policy shock of the core economy, i.e., the U.S.

We claim that our findings could serve as guidance for monetary or exchange rate policymakers. However, we also claim that our reasoning is only suggestive at this moment. Further evidence is needed. Especially for institutional change, micro-level data (loan level and covenant) are needed, though this remains as a future research agenda.

## APPENDIX

## A. Robustness Checks

## 1. Empirical Results: All Periods

In this section, we present the impulse responses of U.S. monetary policies in the form of gross capital flows for all sample periods. In our baseline specification, we split our sample into two bins, before and after the crisis, and analyze each bin independently. The results therein are similar to those analyzed for panel data, for example in Banerjee, Devereux, and Lombardo (2016).

One may instead be interested in running the entire sample while including the global financial crisis period. Consequently, in the appendix, we report the results for this specification. We include a crisis dummy for both the global financial crisis and the East Asian Crisis; the crisis dummy is one for 2008q1-2009q2 and 1997q4-1998q1. Our results are reported in Figure A1 and Figure A2. Unlike the baseline results in section 4, we do not see capital inflows by residents (decrease in assets), nor capital outflows of foreign investors (decrease of liabilities). In Figure A1, capital flows by residents show consistent increases with U.S. monetary policy shocks. This pattern does not vary with different types of flows. Also in Figure A2, we see consistent increases of foreign flows with U.S. monetary policy shocks. The results do not vary even if we include squared time trends as a further control. Overall, we could not recover the patterns observed in other studies.

We conjecture that there is a break in the time trend before and after the crisis. Thus, it is possible that outflows by foreign investors and inflows by residents, which are widely reported in other emerging economies, are only observed if we split the sample and apply different time trend for both economies.

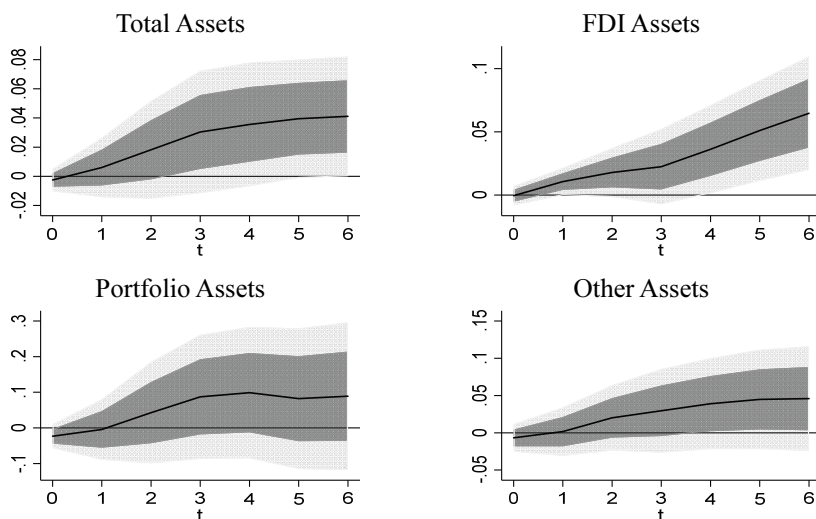


FIGURE A1. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS FOR ASSETS, ALL PERIODS

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks for the logged assets of residents. Light grey shows the 90 percent confidence intervals, while dark grey shows the 68 percent confidence intervals.

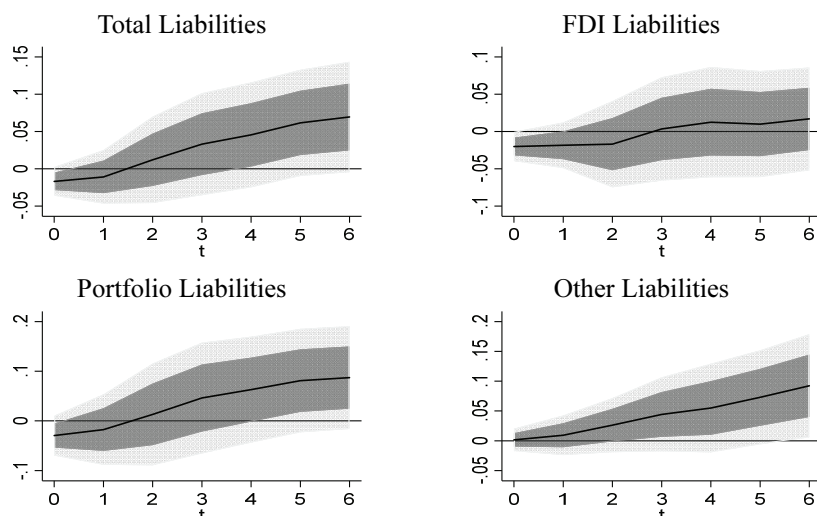


FIGURE A2. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS FOR LIABILITIES, ALL PERIODS

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks in the logged liabilities, i.e., claims of foreign investors. Light grey shows the 90 percent confidence intervals, while dark grey shows the 68 percent confidence intervals.

## 2. Empirical Results: with VIX

In this chapter, we report the results of a specification with the VIX and drop the appreciation of nominal exchange rates. We exclude the VIX as a control in our baseline analysis, as the global risk aversion captured by the VIX can fluctuate due to U.S. monetary policies. Thus, to include the VIX as an extra control while incorporating the shock itself may lead to endogeneity issues. At the same time, it is also possible that there are orthogonal deviations of the VIX with U.S. monetary policies. Thus, we utilize a specification which includes the VIX as a control. Also, we exclude nominal exchange rate appreciation as a control. As a small open economy, the baseline specification presumes that exchange rates vary along with external sources and thus form an exogenous variable. However, it is also plausible that nominal exchange rates are determined endogenously. In a new specification, we exclude nominal exchange rate appreciation and include the VIX as a control. Figure A3 and Figure A4 shows the results.

Overall, our main message is not altered. For capital flows by domestic residents, the declines in the total flows are lower in the after-the-crisis bins. However, the discrepancies are not very notable. On the other hand, portfolio flows show clearer distinctions between the two. While there is a clear hump shape in the before-the-crisis sample, no clear pattern is observed in the after-the-crisis sample. For the foreign capital flows shown in Figure A4, the results are less stark between the samples before and after the crisis. However, the overall images are very similar; the average responses of foreign outflows are weaker than before, and the results are mainly driven by portfolio flows.



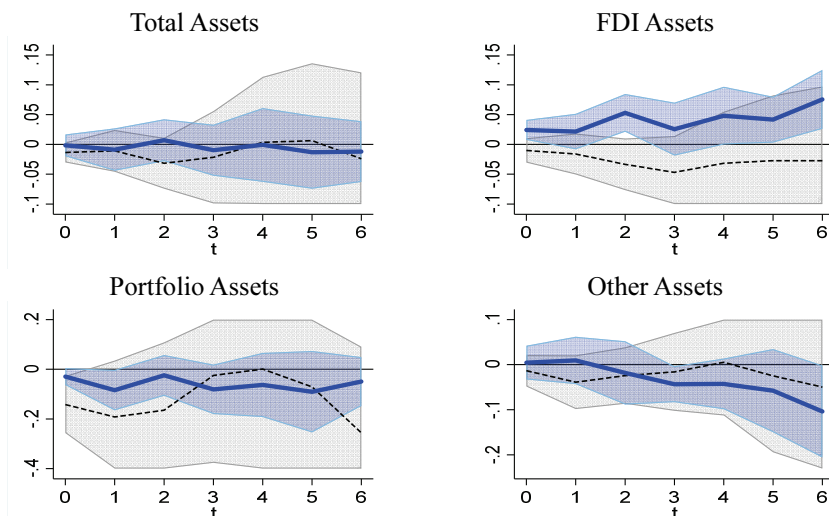


FIGURE A3. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS FOR ASSETS BEFORE AND AFTER THE CRISIS, WITH THE VIX

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks for the logged assets of residents. The solid blue line indicates the results from the after-the-crisis period (2010q1–2019q2), and the dashed line represents the results from the before-the-crisis period (1995q1–2008q4). Here, 90 percent confidence intervals are reported.

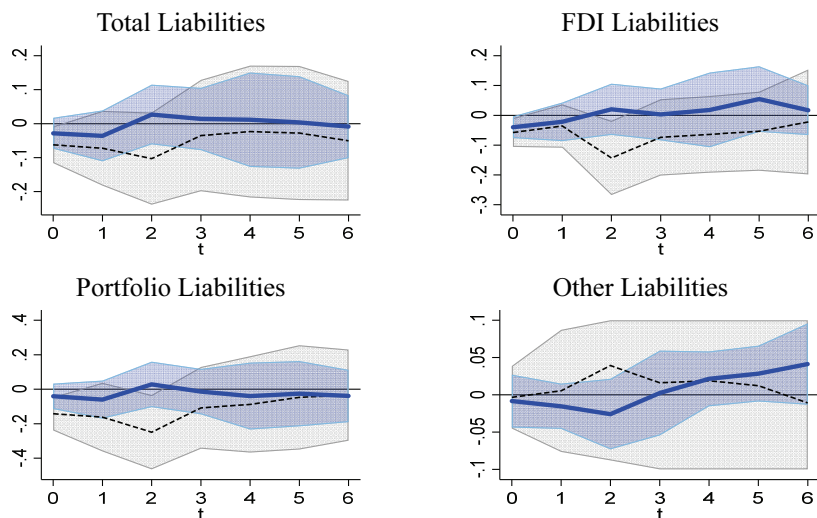


FIGURE A4. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS FOR LIABILITIES BEFORE AND AFTER THE CRISIS, WITH THE VIX

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks for the logged assets of residents. The solid blue line indicates for the results from the after-the-crisis period (2010q1–2019q2), and the dashed line represents the results from the before-the-crisis period (1995q1–2008q4). Here, 90 percent confidence intervals are reported.

### 3. Empirical Results: Other Time Trends

One can expect that the upward or downward pattern can be controlled by with the added t-squared trend. That is, if further controlling a hump-shaped pattern, one

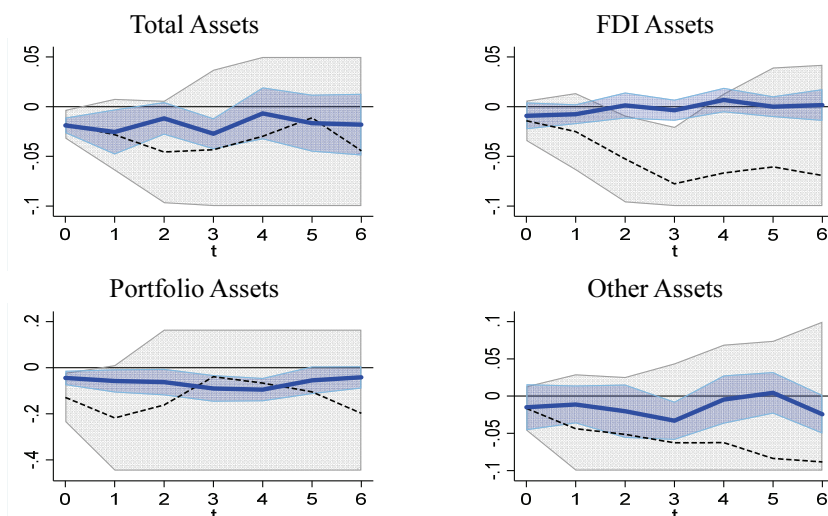


FIGURE A5. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS FOR ASSETS BEFORE AND AFTER THE CRISIS, WITH THE T-SQUARED TREND

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks for the logged assets of residents. The solid blue line indicates the results from the after-the-crisis period (2010q1–2019q2), and the dashed line represents the results from the before-the-crisis period (1995q1–2008q4). Here, the 90 percent confidence intervals are reported.

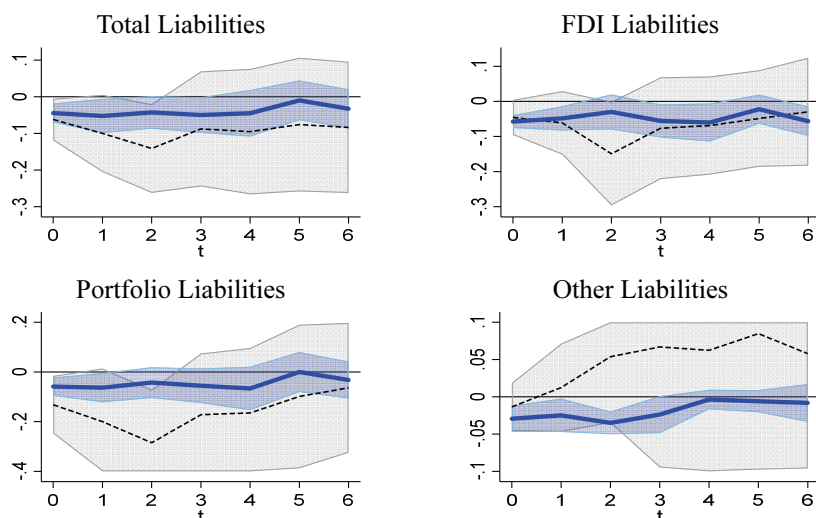


FIGURE A6. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS FOR LIABILITIES BEFORE AND AFTER THE CRISIS, WITH THE T-SQUARED TREND

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks for the logged assets of residents. The solid blue line indicates the results from the after-the-crisis period (2010q1–2019q2), and the dashed line represents the results from the before-the-crisis period (1995q1–2008q4). Here, 90 percent confidence intervals are reported.

may find different implications of the impulse response patterns.

Here, we report the outcomes with the t-squared term included. Again, our overall message does not change. Foreign capital outflows are mostly notable with a U.S. monetary policy shock, and this response is mostly driven by portfolio flows. While

there is less of an upward or downward trend in the FDI or other flows, the results do not alter our overall picture.

#### 4. Empirical Results: Interacting with the Crisis Dummy

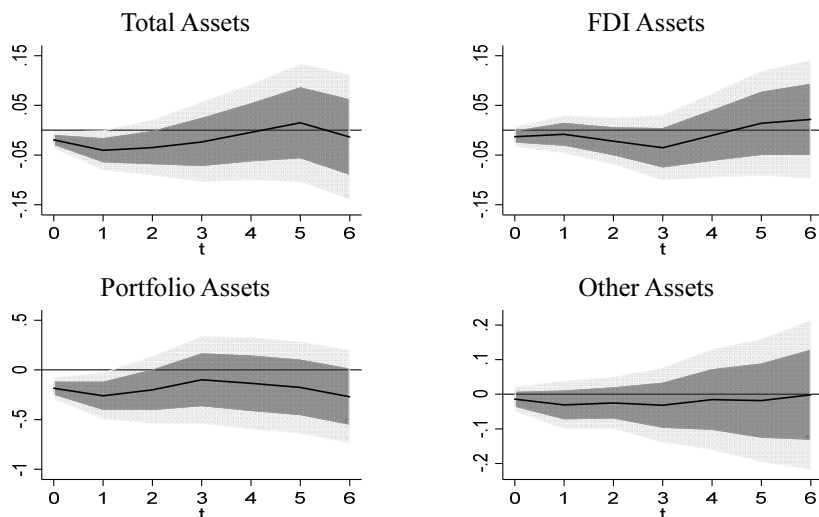


FIGURE A7. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS FOR ASSETS BEFORE THE GLOBAL FINANCIAL CRISIS, INTERACTING CRISIS DUMMY

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks for the logged assets of residents. The sample ranges from 1995q1 to 2008q4. Light grey indicates the 90 percent confidence intervals, while dark grey denotes the 68 percent confidence intervals.

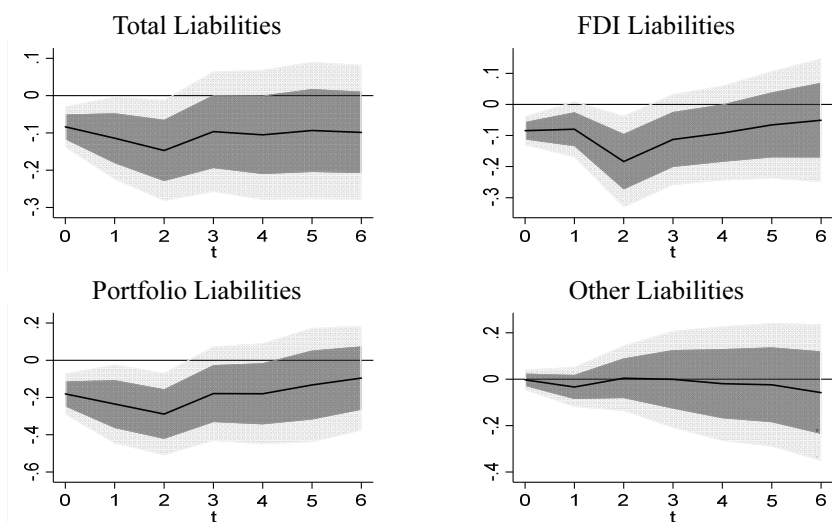


FIGURE A8. IMPULSE RESPONSES TO U.S. MONETARY SHOCKS FOR LIABILITIES AFTER THE GLOBAL FINANCIAL CRISIS, INTERACTING CRISIS DUMMY

*Note:* The figure shows the impulse responses to U.S. monetary policy shocks for the logged assets of residents. The sample ranges from 1995q1 to 2008q4. Light grey indicates the 90 percent confidence intervals, while dark grey denotes the 68 percent confidence intervals.

It is also possible for capital flows to have different responses to a monetary policy shock. Thus, in this chapter we incorporate a crisis dummy with a monetary policy shock for the sample period before the global financial crisis. Here, we utilize two periods: the East Asian Crisis (1997q4-1998q1) and the financial turmoil due to the IT bubble (2003q1-2003q2). Additionally, the new specification only changes the results for before-the-crisis sample, and the results will be identical for the after-the-crisis sample period. Figures A7-A8 correspond to Figures 4 and 5 in our main body. Unfortunately, the results do not vary much from our baseline regression. There is no significant change in the impulse responses of the monetary policy (during the non-crisis state), and the confidence intervals are still very wide and robust. Thus, to mute the large swings during the crisis state, it appears to be sufficient to put a wedge in the capital flows during periods of turmoil.

### B. Full Set of Equations for the Model Simulations

We supplement the full set of equations to simulate Banerjee, Devereux, and Lombardo (2016). It should be noted that we simply assume the Taylor rule as a monetary policy both for core and center economies. Thus, the current set of equations consists of equations from the simplest model presented in Banerjee, Devereux, and Lombardo (2016). Please see Banerjee, Devereux, and Lombardo (2015) for a more in-depth description of the system of equations.

#### 1. Households' Problem

$$E_0 \sum_{t=0}^{\infty} \beta^t \left( \frac{C_t^{e(1-\sigma)}}{1-\sigma} - \frac{H_t^{e(1+\psi)}}{1+\psi} \right)$$

$$C_t^e = \left( \nu^{\frac{1}{\eta}} C_{et}^{e1-\frac{1}{\eta}} + (1-\nu^e)^{\frac{1}{\eta}} C_{ct}^{e1-\frac{1}{\eta}} \right)^{\frac{1}{1-\eta}}$$

$$P_t^e = \left( \nu^e P_{et}^{1-\eta} + (1-\nu^e) P_{ct}^{1-\eta} \right)^{\frac{1}{1-\eta}}$$

$$P_t^e C_t^e + S_t B_t^e = W_t^e H_t^e + \Pi_t^e + R_{t-1}^* S_t B_{t-1}^e$$

$$E_t \Lambda_{t+1}^e \frac{R_t^*}{\pi_{t+1}^e} \frac{S_{t+1}}{S_t} = 1$$

$$\frac{W_t^e}{P_t^e} = C_t^{e\sigma} H_t^{e\psi}$$

$$\Lambda_{t+1}^e \equiv \beta \left( \frac{c_{t+1}^e}{c_t^e} \right)^{-\sigma}, \quad \pi_{t+1}^e \equiv \left( \frac{P_{t+1}^e}{P_t^e} \right)$$

## 2. Capital Goods Producers' Problem

$$P_t^e I_t^e \left( 1 + \zeta \left( \frac{P_t^e I_t^e}{P_{t-1}^e I_{t-1}^e} \right)^2 \right)$$

$$K_t^e = I_t^e + (1 - \delta) K_{t-1}^e$$

## 3. Emerging Market Economies Banks' Problem

$$N_{t,i}^e + RER_t V_{t,i}^e = Q_t^e K_{t+1,i}$$

$$RER_t = \frac{(S_t P_t^c)}{p_t^e}$$

$$N_{t,i} = R_{k,t}^e Q_{t-1}^e K_{t,i}^e - RER_t R_{ct-1} V_{t-1,i}^e$$

$$J_{t,i}^e \geq \kappa_t^e Q_t^e K_{t+1,i}^e$$

$$\text{Max}_{t,i} J_{t,i}^e \left[ K_{t+1,i}^e, V_{t,i}^e \right] = E_t \Lambda_{t+1}^e \left[ (1 - \theta) (R_{k,t+1}^e Q_t^e K_{t+1,i}^e - RER_{t+1} R_{ct} V_{t,i}^e) + \theta J_{t+1,i}^e \right]$$

$$N_{t+1}^e = \theta \left( \left( R_{kt+1}^e - \frac{RER_{t+1}}{RER_t} R_{c,t} \right) Q_t^e K_t^e + \frac{RER_{t+1}}{RER_t} R_{c,t} N_t^e \right) + \delta_T Q_t^e K_{t-1}^e$$

$$Y_t^e = A_t^e H_t^{e(1-\alpha)} K_{t-1}^{e(\alpha)}$$

$$R_{kt+1}^e = \frac{R_{zt+1}^e + (1 - \delta) Q_{t+1}^e}{Q_t^e}$$

$$MC_{et} (1 - \alpha) A_t^e H_t^{e(-\alpha)} K_{t-1}^{e(\alpha)} = W_{rt}^e$$

$$MC_{et} \alpha H_t^{e(1-\alpha)} K_{t-1}^{e(\alpha-1)} = R_{zt}^e$$

$$\Pi_{et}^* = \frac{\sigma_p}{\sigma_p - 1} \frac{F_{et}}{G_{et}} \pi_{et}^{ppi}$$

$$F_{et} = Y_{et} MC_{et} + E_t \left[ \beta \zeta \Lambda_{t,t+1}^e \pi_{et+1}^{ppi \eta} F_{et+1} \right]$$

$$G_{et} = Y_{et} P_{et} + E_t \left[ \beta \zeta \Lambda_{t,t+1}^e \pi_{et+1}^{ppi - (1-\eta)} G_{et+1} \right]$$

$$\pi_{et}^{ppi 1-\eta} = \zeta + (1 - \zeta) (\Pi_{et}^*)^{1-\eta}$$

#### 4. Monetary Policy

$$\log R_t = \lambda_{r,e} \log R_{t-1} + (1 - \lambda_{r,e}) \left( \lambda_{\pi,e} \log \left( \frac{\pi_t^e}{\pi_{ss}^e} \right) + \lambda_{y,e} \log \left( \frac{Y_t^e}{Y_{ss}^e} \right) \right) + \varepsilon_{r,t}^e$$

#### 5. Center Country's Optimization Problem

$$E_0 \sum_{t=0}^{\infty} \beta^t \left( \frac{C_t^{c(1-\sigma)}}{1-\sigma} - \frac{H_t^{c(1+\psi)}}{1+\psi} \right)$$

$$P_t^c C_t^c + B_t^c = W_t^c H_t^c + \Pi_t^c + R_t^* B_t^c + T_t^c$$

#### 6. Center Country Banks' Problem

$$V_{jt}^e + Q_t^c K_{jt}^c = N_{jt}^c + B_t^c$$

$$J_{jt}^c = E_t \max_{K_{j,t+1}^c, V_{jt}^c, B_t^c} \Lambda_{t+1}^c \left[ (1-\theta) \left( R_{kt+1}^c Q_t^c K_{jt}^c + R_{ct} V_{jt}^e - R_t^* B_t^c \right) + \theta J_{jt+1}^c \right]$$

$$J_{jt} \geq \kappa_t^c (V_{jt}^e + Q_{ct} K_{jt}^c)$$

$$N_{t+1}^c = \theta \left( (R_{kt+1}^c - R_t^*) Q_t^c K_t^c + (R_{c,t} - R_t^*) V_t^e + R_t^* N_t^c \right) + \delta_T Q_{t+1}^c K_{t-1}^c$$

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## Trick or Treat? Equity Concerns in the Preliminary Feasibility Study of the Republic of Korea<sup>†</sup>

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*As a project appraisal tool, the preliminary feasibility study (PFS) has contributed to enhancing the efficiency of public investment decision-making in the Republic of Korea over the last two decades. To overcome the limitations of the efficiency-oriented cost-benefit analysis, the PFS accommodates equity concerns among regions, namely balanced regional development (BRD) analysis. This study attempts to gauge the contributions of BRD analysis to PFS results. Specifically, it addresses how effectively policy efforts to promote decision-making have been implemented in the PFS stage while also considering the balance between equity and efficiency in terms of the trade-off between them, the degree to which they influence the results, and whether the consideration of equity is in fact actually reflected in seriously underdeveloped regions as intended. The study finds that the PFS results over the last two decades have been largely in line with the background and policy objectives. Based on the findings of the study, needs for institutional improvement are suggested, including enhancements in the analysis of regional economic ripple effects and taking into account the psychological factors pertaining to the evaluators in the overall judgment.*

Key Word: Equity-efficiency Trade-off, Balanced Regional Development,  
Project Appraisal Preliminary Feasibility Study  
JEL Code: H43, H54, R53, D61

### I. Introduction

The preliminary feasibility study (PFS) was devised and first carried out in 1999 for efficient and objective public investment management in the course of overcoming the 1997 Asian financial crisis in the Republic of Korea. The *ex ante* appraisal of large-

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scale public investment projects is considered to have contributed greatly to securing fiscal soundness and increasing the efficiency of public investments by preventing unnecessary budget waste over the past 20 years.

More precisely, the PFS has helped the budget authority to make informed decisions by providing high-quality information and has raised the quality of discussions during the negotiation process by alleviating the information asymmetry between the budget authority and line ministries. In addition, the PFS of the Republic of Korea has been recognized for its objectivity and transparency, which were secured by continuously improving the evaluation methodology and providing a buffer from political influence due to its management by an independent center of excellence, namely the Korea Development Institute (KDI)'s Public and Private Infrastructure Investment Management Center (PIMAC).

However, there have also been a number of negative assessments, as the line ministries and local governments that want to implement the project in relatively underdeveloped areas would be at a disadvantage due to the lack of sufficient prerequisites. In the course of the operation of the PFS over the last two decades, the response to this problem has been to include not only an efficiency-oriented cost-benefit analysis (CBA) in the name of "economic analysis" but also an equity-centered "balanced regional development (BRD) analysis" when making comprehensive recommendations to the budget authority.

The point of the BRD analysis is to supplement the limitations of the CBA by adding extra points to projects to be implemented in relatively underdeveloped regions. Moreover, by steadily increasing the range of prior weights devoted to the BRD analysis, the consideration of equity among regions has been heightened as part of the effort to utilize the trade-off between equity and efficiency as pursued by BRD and CBA analyses, respectively.

The purpose of this study is to present a quantitative assessment of the contribution of the BRD analysis to PFS results by analyzing the PFS cases conducted over the past 20 years. In particular, we seek to provide insight into how effectively policy efforts to promote decision-making have been implemented in the PFS stage, considering the balance between equity and efficiency in terms of the trade-off between them, how much they have influenced the results, and whether the consideration of equity was actually reflected in the seriously underdeveloped regions as intended. This will enable us to evaluate the past performance, draw implications, and make policy suggestions for future institutional improvement.

This study finds that the results of PFSs over the last two decades have been largely in line with the background and policy objectives of considering BRD systematically and gradually expanding its weight. However, because the analysis was at times limited to the discovery of facts, an in-depth investigation to identify reasons for specific results remains outside of the scope of this study and will be left as a future research project. Moreover, due to analytical burden, samples were analyzed rather than surveyed in some cases, which means that a cautious interpretation is required.

Based on the results of this study, we attempted to make suggestions that we feel will improve the PFS system in the future, especially considering the significant changes since 2019. Policy suggestions can be summarized as improvements in the analysis of regional economic ripple effects and the consideration of the psychological factors

of the evaluators in the overall judgment.

The rest of this paper is structured as follows. Section II provides an overview of the BRD analysis in the PFS, including why it is needed, its evaluation elements, and chronological changes. Section III attempts to evaluate the effectiveness of the BRD analysis according to three aspects: (a) whether the policy intention was effectively materialized in the PFS, (b) whether the results were influenced by the equity-efficiency trade-off, and (c) whether equity was of greater concern in more severely underdeveloped regions in relation to the policy goals. Finally, Section IV is devoted to summarizing the policy implications and making policy suggestions.

## II. Overview of the BRD Analysis in the PFS

### *A. Need for the BRD Analysis*

Using the analytic hierarchy process (AHP) as a tool to help with decision making by facilitating pairwise comparisons of multiple evaluation components, the overall judgement of a PFS follows a method of synthesizing the results of three evaluation components: economic feasibility, policy adequacy, and contribution to BRD. During this process, while none of the components takes precedence over others, the component with the highest prior weight is economic feasibility. By using the term “economic,” the analysis of this component is sometimes confused with a “financial” analysis that compares revenue and expenditures according to the project implementation. However, the main methodology of the economic analysis is a CBA.

A CBA compares the “social cost” and “social benefit” that occur over the entire lifecycle of the project and is not related to the revenue obtained as a result of operating the project. For example, in the case of a national museum, where admission is free, revenue from its operation is obtained mainly by selling souvenirs or food and beverages. Accordingly, the revenue will be very small compared to the construction and operation costs. Therefore, according to a financial analysis, the construction of the national museum will be difficult to secure. However, if we use a CBA to estimate social benefits, such as willingness to pay (WTP) for museum visits or its mere existence, we can find projects that secure economic feasibility. This logic applies equally to economic infrastructure, such as national roads that do not collect user fees and even toll roads where users are in fact charged.

In this way, an economic analysis by means of a CBA can be a stand-alone criterion for judging the feasibility of a project. In countries such as Denmark, Greece, Ireland, Portugal, and Spain, transportation projects have been evaluated solely on the basis of a CBA (Leleur, 2000, cited in Park *et al.*, 2001, Table II-1, p.38).

In many cases, the method of calculating benefits in a CBA is to take the product of the unit value and the quantity of the identified benefit item, where the quantity is calculated based on the estimated demand. In general, demand estimates may be favorable in areas that are already developed. In other words, already developed regions tend to have relatively large populations with high incomes; accordingly, *ceteris paribus*, it is likely that the demand for the project to be estimated as relatively high. Such a phenomenon may be more noticeable when the benefits are concentrated in a specific area, such as a metro or a science museum, than when the benefits are

distributed in various areas, such as inter-regional roads and railroads.

Therefore, relying only on the results of a CBA to determine the feasibility of a project and allocate budget for it can ultimately result in exacerbating regional disparities, or the so-called “the rich get richer and the poor get poorer” phenomenon, by allocating projects in areas that have already been developed. Of course, the logical basis of a CBA is the Kaldor-Hicks efficiency, in which the members of society who are worse off due to the implementation of the project can be compensated “virtually” to be at least indifferent to the status quo by the excess of the net social benefits when the social benefits outweigh the social cost. Thus, even if projects are concentrated in already developed areas, it can be said that no logical problem exists as long as proper compensation is provided in any form from the benefited areas to the disadvantaged ones. However, in practice, it is difficult to provide such compensation accurately. Moreover, if indirect ripple effects not reflected in the CBA or effects that are difficult to quantify are considered, the concentration of the project may become a major problem.

In this regard, in the PFS, the “regional backwardness analysis” was included as a mechanism to improve the equity of budget allocation by adding points to underdeveloped areas. In other words, by examining the relative backwardness of cities and counties across the country and ranking them, additional points can be given to regions with low rankings (relatively backward). Accordingly, an equity-efficiency trade-off is inevitable. The CBA is a scientific tool that has continually improved its methodology with regard to curbing inefficient projects, and the efficiency evaluation function can be weakened by the consideration of equity, and vice versa.

In addition, considering the relative size of the added-value creation effect in certain regions when carrying out projects, the “regional economic ripple effect analysis,” which gives additional points when the effect is large, is also considered. This is based on the “cost-effectiveness” of selecting an alternative that has a greater effect for the same cost input or a less expensive alternative for the same effect.

### *B. Data and the Econometric Methodology*

In the BRD analysis of the PFS, the RBI is calculated according to the weighted sum of selected indicators that can reveal the extent of development in the region in question. As shown in Table 1, there were initially five indicators that make up the RBI, but this number was expanded to eight. The indicator values are updated periodically (for a detailed definition and for the source of the indicators, see KDI, 2008, Table 4-2, p.100).

The RBI for region  $r$  at time  $t$  is calculated as

$$RBI_t^r = \sum_{i=1}^8 W_i \cdot Z_{it_i(t)}^r$$

where  $W_i$  is the (time-invariant) weight assigned to indicator  $i$ , and  $Z_{it_i(t)}^r = (X_{it_i(t)}^r - \bar{X}_{it_i(t)}) / S_{it_i(t)}$ , in which  $X_{it_i(t)}^r$  is the indicator  $i$ 's value in

TABLE 1—CHRONOLOGY OF THE REGIONAL BACKWARDNESS INDEX

General guidelines edition			1st	2nd-3rd	4th-5th
Indicator	Popul- ation	Population growth	Y	Y	Y
		Aging index		Y	Y
	Economy	Fiscal independence	Y	Y	Y
		Manufacturing employment per capita	Y	Y	Y
		Registered vehicles per capita		Y	Y
	Infra- structure	Road ratio	Y	Y	Y
		Doctors per capita		Y	Y
		Urban utilization		Y	Y
	Average land price		Y		
	No. of indicators			5	8
Calculating index with indicators			Simple average	Weighted sum	Weighted sum
Target areas			Municipalities	Municipalities	Provinces and Municipalities

Source: Adapted from Kim and Cho (2018), Table 4, p.294.

TABLE 2—WEIGHTS ON INDICATORS FOR THE REGIONAL BACKWARDNESS INDEX

Indicator	Weight (%)	Indicator	Weight (%)
Population growth	8.9	Registered vehicles per capita	12.4
Aging index	4.4	Road ratio	11.7
Fiscal independence	29.1	Doctors per capita	6.3
Manufacturing employment per capita	13.1	Urban utilization	14.2

Source: Korea Development Institute (2008), Table 4-3, p.101.

region  $r$  at time  $t_i(t)$ , and  $\bar{X}_{it_i(t)}$  and  $S_{it_i(t)}$  are the average and standard deviation of indicator  $i$ , respectively (Korea Development Institute, 2008, p.99 and p.101). The subscript  $t_i(t)$  represents the most recent time point before time  $t$  for which the data of indicator  $i$  are available. Meanwhile, the weight  $W_i$  was set as shown in Table 2 as a result of an expert survey.

C. Estimating the Ripple Effect in the Regional Economy

In the regional economic ripple effect analysis, the region-specific value-added effect of the project implementation is estimated using the interregional input-output (IRIO) model, which is constructed by combining estimates such as the value-added by region and sector, regional final demand, and regional trade factors. The “IRIO index” is calculated by comparing it with the gross regional domestic product (GRDP) in the region, after which a qualitative evaluation is conducted when a comprehensive judgment of the feasibility of the project is made.

TABLE 3—EXAMPLE OF CALCULATING THE RIPPLE EFFECT ON THE REGIONAL ECONOMY

Alternative	High cost	High cost	Low cost
Total project cost (bil KRW)	206.94	206.94	139.38
Region	Province A	Province B	Province B
Induced value-added in the region (bil KRW)	100.33	113.58	76.50
GRDP (bil KRW)	34,258.26	58,439.70	58,439.70
IRIO index (%)	0.2929	0.1944	0.1309

Table 3 compares the hypothetical results of the calculation of the IRIO index. It is assumed that two projects with different total project cost (TPC) levels (high and low cost alternatives) will be implemented and that two regions with different GRDP levels (Provinces A and B) will be considered. When projects with the same TPC (KRW 206.94 billion) are implemented in different regions, the difference in the size of the induced value-added in the region is smaller than that between the GRDPs in the two regions, resulting in a difference in the IRIO index. The IRIO index is a value obtained by dividing the induced value-added in the region by the GRDP of the region. Accordingly, even if the same project is pursued, the index value of the region where the GRDP is low is generally large. If two projects with different TPCs are implemented in the same area (Province B), the value of the IRIO index increases when a relatively large project is implemented, as the GRDP is fixed. In summary, we can conclude that, *ceteris paribus*, a lower GRDP and a higher TPC would be advantageous in the regional economic ripple effect analysis.

#### D. Status Enhancement of the BRD Analysis

The BRD analysis, composed of the regional backwardness analysis and the regional economic ripple effect analysis, was separately considered from the beginning of the introduction of the PFS to overcome the limitations of a CBA, as discussed above. However, the status of the BRD analysis gradually increased over time. There are two main status enhancements. First, in the AHP analysis used for making a comprehensive judgment, the hierarchy of the regional backwardness and regional economic ripple effect analyses corresponding to the BRD analysis was upgraded from the second to the first tier. Second, the weight to the BRD analysis has increased since it was upgraded to the first tier.

The new stratification of the BRD analysis began in 2006, as shown in Figure 1. The regional backwardness and the regional economic ripple effect analyses, which were included as a policy analysis item before that point in time, were separated out to the new first-tier BRD analysis after 2006, which changed the AHP analysis structure. This measure was taken to make the results of the BRD analysis more explicit and complementary in the same phase as the results of an economic analysis.

However, the relative pre-weight of the BRD analysis was set to be lower than that of the economic analysis (40-50 percent) by assigning pre-weights in the range of 15-25 percent in 2006 (hereafter, the term “pre-weight” refers to the specified range of weight of each analysis component so that evaluators can provide a weight value of their choosing within it). As discussed above, this can be understood as not overriding the efficiency in view of the trade-off between equity and efficiency.

Since then, the consideration of equity has been strengthened, which can be confirmed by the trend of the increasing pre-weight of the BRD analysis since 2006, as shown in the lower right area of Figure 1. The pre-weight of the BRD analysis has gradually increased over several years and, after 2019, the BRD analysis was changed to give additional points only for non-Seoul Metropolitan Areas (non-SMAs). Arguably, this was intended to strengthen equity consideration across the country, as there are many relatively developed areas that receive deductions rather than extra points in the SMA, while non-SMAs consist of relatively less developed areas that are the beneficiaries of additional points in the BRD analysis.

### **III. Evaluating the Effectiveness of the BRD Analysis in the PFS**

In this section, we attempt to measure the effectiveness of the BRD analysis based on the experience of considering the component corresponding to concern for equity in the overall judgment of the feasibility of the project. In so doing, we take into account three aspects of effectiveness: (a) whether the policy intention was effectively materialized in the study, (b) whether the results were influenced by the trade-off between equity and efficiency, and (c) whether equity was of greater concern in more severely underdeveloped regions according to the policy goals.

First, in the context of the increasing magnitude of the range of weights of the BRD analysis within the PFS since 2006, we examine whether such a change in the pre-weight has influenced the weight actually assigned by evaluators. Through this exercise, it is possible to understand whether the policy intention that was pursued considering equity more in the PFS was effectively implemented in reality.

Second, we analyze the pattern by which the evaluation results according to efficiency standards are reversed by considering equity due to the trade-off between equity and efficiency. There may be a case in which economic feasibility is not secured as a result of an economic analysis according to the efficiency standard but the overall feasibility is concluded by summing up the results of the BRD analysis according to the equity consideration, and vice versa. The occurrence of such discrepancies between the economic and overall feasibilities is referred to as a “feasibility reversal.” By observing the frequency and trend of such reversals, it is possible to obtain a policy implication that seeks to achieve a balance between equity and efficiency.

Third, we evaluate the differential contribution of the BRD analysis according to the development of the region in question. When the policy goal of introducing and strengthening the BRD analysis is to give greater consideration to equity in the PFS, the results of the BRD analysis should actually be more vigorously reflected in areas with severe backwardness.

The data obtained for analysis consist of a total of 704 PFS results that were completed between 1999 and 2018. The results include the completion year of the PFS; the type and scale (TPC) of the project; the benefit-to-cost ratio (BCR); evaluation points of economic, policy, and BRD analyses; and the AHP score. Some specific analyses may use part of the data depending on the context, and the range of data used at each time will be specified.

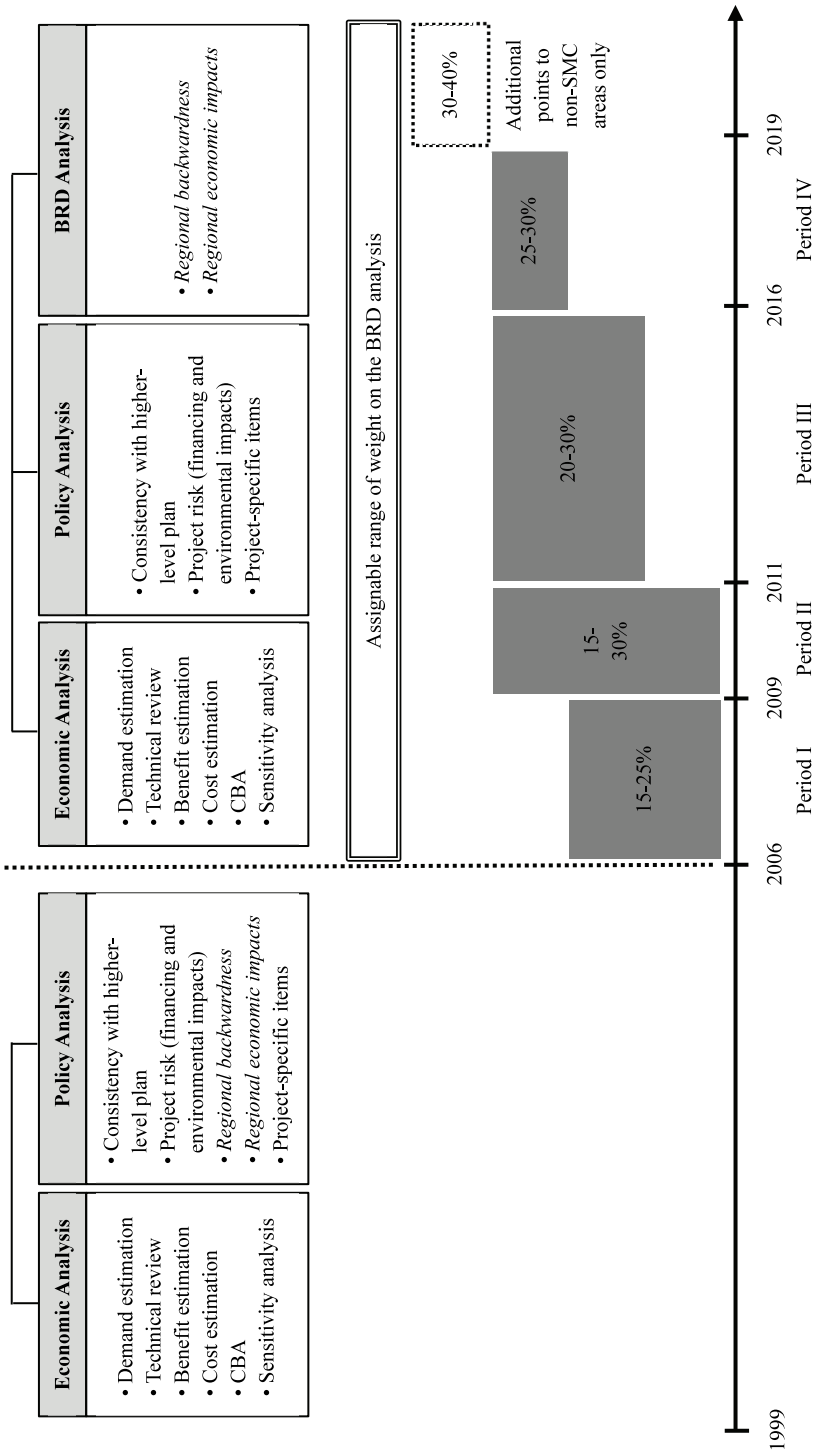


FIGURE 1. CHANGE OF STRUCTURE OF COMPREHENSIVE EVALUATION FRAMEWORK AND WEIGHT ON BALANCED REGIONAL DEVELOPMENT ANALYSIS



A. Effect of Raising the Pre-weight of the BRD Analysis

To examine whether the policy intention to strengthen the consideration of equity gradually was actually implemented in the PFS, we analyzed the trend of the actual assigned weights in the results of the PFS since 2006, when the BRD analysis was upgraded to the first tier. Figure 2 shows the annual averages of assigned weights to economic, policy, and BRD analyses in the AHP evaluations during the overall evaluation of the 449 PFSs conducted in the period of 2006-18. It can be seen that the annual average weight actually assigned to the BRD analysis by AHP evaluators gradually increases during the period.

For a clearer understanding of the increasing trend, we carried out quantitative analyses using ordinary least square (OLS) regression models. In addition to the time when the PFS is conducted, additional factors possibly affecting the actual weight on the BRD analysis include the type, location, scale, and economic feasibility of the project, among others. Table 4 shows the dependent and explanatory variables used in the regression models depending on data availability.

The types of projects were treated as dummy variables to determine whether road, railroad, construction, water resources, and port projects caused differences in weight assignments to the BRD analysis compared to other types. The benchmark group here included airports, industrial complexes, and health facilities, to name a few. A project may be carried out across several regions, especially network projects such as roads and railroads, making it difficult therefore to identify regional differences clearly. Therefore, by using a dummy variable, we attempted to compare cases in which the project site includes a region in the SMA (i.e., Seoul, Incheon, and Gyeonggi-do) to those where it does not. There may be several variables indicating the size of the project, but the total project cost (TPC)—the only information that can be obtained from the data—is included in trillion Korean won (KRW) units. One of the 449 PFSs in the data was missing the TPC value. Lastly, we included the benefit-to-cost ratio (BCR) obtained as a result of the CBA to examine the impact of the results, in that the evaluator knows the economic feasibility analysis results when performing the AHP evaluation and weighting the BRD analysis.

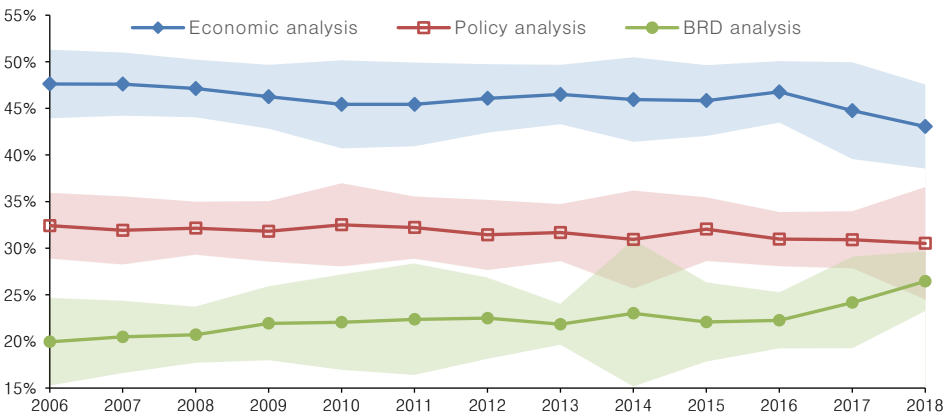


FIGURE 2. TREND OF THE PRE-WEIGHTS ON FIRST-TIER AHP EVALUATION COMPONENTS: 2006-2018

Note: The shaded area represents the 95 percent confidence interval.

TABLE 4—SUMMARY STATISTICS OF VARIABLES IN REGRESSION ANALYSES

Variable	Description	N	Mean	Std. Dev.	Max	Min
Weight on BRD analysis	Actual weight given to the BRD analysis (dependent variable)	449	0.2204	0.02795	0.15	0.369
Year	Year the PFS is conducted	449	2011.016	3.663	2006	2018
Seoul Metropolitan Area	Dummy variable = 1 if the project site includes Seoul Metropolitan Area	449	0.3007	0.4591	0	1
Roads	Dummy variable = 1 if the project is a road project	449	0.3519	0.4781	0	1
Railroads	Dummy variable = 1 if the project is a railroad project	449	0.1826	0.3868	0	1
Culture/Tourism	Dummy variable = 1 if the project is a cultural or tourism project	449	0.1136	0.3177	0	1
Water resources	Dummy variable = 1 if the project is a water resources project	449	0.09131	0.2884	0	1
Ports	Dummy variable = 1 if the project is a port project	449	0.06682	0.2500	0	1
Total project cost	Total project cost in tril. KRW	448	0.5877	1.485	0.0452	13.06
Benefit to cost ratio	Benefit to cost ratio obtained in the economic analysis	449	1.040	0.9381	0.0110	16.21

One may argue that the year variable potentially suffers from the endogeneity problem if many new AHP evaluators in the later comprehensive evaluations assign greater weights to the BRD analysis as compared to earlier evaluations systematically for certain unidentified and unobserved reasons. However, a trend in this direction is highly unlikely to exist considering the composition of the evaluators in the comprehensive evaluation. For all PFS cases, the Executive Director and the Director of PIMAC participate in the comprehensive evaluations throughout the data period. Other AHP evaluators in the comprehensive evaluations consist of the project manager who is in charge of the study and outside experts such as university professors and engineering field specialists who have repeatedly conducted PFSs in many cases. Moreover, in practice, consistency between PFSs has been emphasized within PIMAC, with clear instructions at the beginning of each wave of PFSs. In this case, individual effects other than policy changes on the pre-weights of the BRD analysis may be limited. Unfortunately, it is impossible to investigate this issue further due to data limitations in that information pertaining to individual evaluators is not disclosed.

Table 5 shows the results of regression analyses using different combinations of these variables as explanatory variables. The increase in the BRD weights as the evaluation year passed, which is our main concern, was statistically significant in all model specifications. In model V, which is the full model using all explanatory variables, the weight given to the BRD analysis increases by 0.371 percent points on average when the evaluation time was one year later and is statistically significant at the 1 percent significance level.

If the project site includes a region in the SMA, the actual weight to the BRD analysis decreases by 1.332 percent points compared to non-SMA projects. The causes

TABLE 5—REGRESSION RESULTS OF THE ACTUAL WEIGHT ON THE BRD ANALYSIS I: YEAR EFFECT

Variable	Model I	Model II	Model III	Model IV	Model V
Year	0.003565*** (0.0003116)	0.003703*** (0.0003074)	0.003675*** (0.0003049)	0.003712*** (0.0003049)	0.003710*** (0.0003045)
Seoul Metropolitan Area		-0.01363*** (0.002153)	-0.01392*** (0.002156)	-0.01357*** (0.002172)	-0.01332*** (0.002180)
Roads			-0.002272 (0.004051)	-0.002215 (0.004058)	-0.002338 (0.004063)
Railroads			-0.001582 (0.004142)	-0.000083 (0.004287)	0.0004845 (0.004306)
Culture/Tourism			-0.01283*** (0.004666)	-0.01311*** (0.004665)	-0.01297*** (0.004692)
Water resources			-0.001579 (0.004768)	-0.002362 (0.004784)	-0.001484 (0.004882)
Ports			-0.01044* (0.005420)	-0.01055* (0.005400)	-0.009274 (0.005155)
Total project cost (tril. KRW)				-0.001289*** (0.0005506)	-0.001326** (0.0005406)
Benefit to cost ratio					-0.002167* (0.001126)
Constant	-6.949*** (0.6265)	-7.223*** (0.6180)	-7.163*** (0.6127)	-7.237*** (0.6127)	-7.230*** (0.6118)
No. of observations	449	449	449	448	448
R-squared	0.2183	0.2681	0.2899	0.2938	0.2988

Note: Numbers in parentheses refer to the heteroscedasticity-robust standard errors. Asterisks indicate statistical significance: \*,  $p < 0.1$ ; \*\*,  $p < 0.05$ ; \*\*\*,  $p < 0.01$ .

of this outcome need to be analyzed further in different ways, but it shows that economic feasibility is considered to be more important for projects in the SMA.

Looking at the changes according to the type of project, roads and railroads, which are network-type projects, did not show statistically significant differences from the benchmark group. The same results were found for water resource and port projects. Only for cultural and tourism projects did the estimation result reveal that the evaluators assigned smaller weights to the BRD analysis by 1.297 percent points as compared to the benchmark group, which is statistically significant at the 1 percent significance level.

Both the scale and economic feasibility of a project affect the weight to the BRD analysis, which is statistically significantly in a negative direction. The larger the scale (TPC) is, the lower the weight becomes to the BRD analysis. This result suggests that evaluators tend to place more emphasis on economic feasibility for relatively large projects. The negative effect of BCR on the weight in the BRD analysis implies that there is no evidence that evaluators, *ceteris paribus*, attempted to compensate for the lack of economic feasibility with the BRD analysis. We will revisit this issue later in this paper.

Similarly, to examine the changes in the actual weighting directly according to changes in the pre-weights for the BRD analysis, we conducted OLS using dummy variables for periods of institutional changes, as shown in Figure 1. In so doing, the data for the years in which the pre-weights changed (2009, 2011, and 2016) were excluded from the analysis because which pre-weight was used was unclear, before

or after the change. Then, given that the second period contains only one year (2010), the period was set as a benchmark group.

Table 6 displays the results of regression analyses using different combinations of explanatory variables with dummy variables for periods. Upon an examination of the change in the actual weight of each period, which is our main interest, there was no statistically significant difference between 2010 and the period immediately after it (Period III: 2012-2015). However, the periods before 2010 and after Period III were statistically significantly different from 2010. The actual weight to the BRD analysis in Period I (2006-2008) and Period IV (2017-2018) is statistically significantly smaller and greater than that in 2010, respectively. More precisely, the actual weight to the BRD analysis in Period I was 1.778 percent points lower than those in Periods II and III (2010-2015 excluding 2011) on average in Model V. The same weight in Period IV was 3.026 percent points higher than those in Periods II and III. These results imply that a greater increase of the lower-bound of the pre-weight range is needed compared to the increase of its upper bound for the policy intention to be effective. That is, failing to find a statistically significant difference between Periods II and III may be a sign that a five percentage point increase of the lower bound of the pre-weight range is not sufficient to observe any significant

TABLE 6—REGRESSION RESULTS OF THE ACTUAL WEIGHT TO THE BRD ANALYSIS II: EFFECT BY PERIOD

Variable	Model I	Model II	Model III	Model IV	Model V
Period I (2006-2008)	-0.01717*** (0.004480)	-0.01849*** (0.004210)	-0.01725*** (0.004233)	-0.01734*** (0.004255)	-0.01778*** (0.004247)
Period III (2012-2015)	0.004318 (0.004918)	0.004466 (0.004630)	0.005564 (0.004647)	0.006049 (0.004701)	0.005463 (0.004711)
Period IV (2017-2018)	0.03035*** (0.005310)	0.02975*** (0.005098)	0.03044*** (0.005011)	0.03056*** (0.005022)	0.03026*** (0.005103)
Seoul Metropolitan Area		-0.01252*** (0.002556)	-0.01281*** (0.002540)	-0.01245*** (0.002563)	-0.01222*** (0.002569)
Roads			-0.002522 (0.004846)	-0.002450 (0.004846)	-0.002687 (0.004862)
Railroads			-0.002274 (0.004980)	-0.0002126 (0.005150)	-0.0008575 (0.005203)
Culture/Tourism			-0.01544*** (0.005397)	-0.01564*** (0.005391)	-0.01551*** (0.005453)
Water resources			-0.005076 (0.006433)	-0.005317 (0.006442)	-0.003983 (0.006589)
Ports			-0.01250* (0.006671)	-0.01251* (0.006633)	-0.01071* (0.006204)
Total project cost (tril. KRW)				-0.001462*** (0.0004361)	-0.001486*** (0.0004355)
Benefit to cost ratio					-0.002444** (0.001029)
Constant	0.2206*** (0.004092)	0.2252*** (0.003956)	0.2288*** (0.005529)	0.2290*** (0.005541)	0.2319*** (0.005848)
No. of observations	328	328	328	328	328
R-squared	0.3110	0.3505	0.3787	0.3837	0.3908

Note: Numbers in parentheses refer to the heteroscedasticity-robust standard errors. Asterisks indicate statistical significance: \*,  $p < 0.1$ ; \*\*,  $p < 0.05$ ; \*\*\*,  $p < 0.01$ .

change. In contrast, the increase of the upper bound given the identical magnitude from Period I to Period II leads to a statistically significant difference.

The effects of other explanatory variables were similar to those in the results of the previous analysis shown in Table 5. The only difference was that ports had a lower actual weight to the BRD analysis compared to the benchmark group at the 10 percent significance level.

From these results, we can infer that the policy intention to strengthen the consideration of the BRD analysis has been realized. The results of the first set of analyses shown in Table 5 confirmed that the actual weight to the BRD analysis increased in a statistically significantly manner by year. Furthermore, as a result of the second set of analyses shown in Table 6, a statistically significant increase was found between Periods I and III, despite the assignment of the same weight within the range of 20 to 25 percent in Periods I through III.

B. Feasibility Reversal

Next, we examined how the feasibility reversal effect was expressed when the result of the BRD analysis corresponding to the equity criteria reversed the result of the economic analysis of the efficiency criterion in the overall evaluation of the PFS. To this end, among the total of 704 studies completed between 1999 and 2018, 696 cases that included a comprehensive evaluation using AHP were analyzed. At this time, if a PFS assumed several scenarios and an AHP was conducted for each scenario, each was regarded as a stand-alone comprehensive evaluation. After dividing the projects with and without economic feasibility into BCR greater than or equal to and less than one, and dividing the overall feasibility determination result based on the AHP score of 0.5, the results were obtained, as shown in Table 7.

When economic feasibility is secured ( $BCR \geq 1$ ) and overall feasibility is secured ( $AHP \geq 0.5$ ), there is no change between the two feasibility outcomes, or the feasibility is “retained.” Likewise, if neither economic feasibility nor comprehensive feasibility is secured ( $BCR < 1$  and  $AHP < 0.5$ ), the feasibility is also “retained.” These cases of retention accounted for 44.7 percent and 36.5 percent of the total, respectively. When combined, they constituted 81.2 percent of the total. Feasibility reversals occurred in the remaining 18.8 percent, and this fact alone suggests that the role of the BRD analysis based on equity standards was significant.

TABLE 7—COMPARISON BETWEEN ECONOMIC AND OVERALL FEASIBILITIES

Economic feasibility	Overall feasibility	Change in feasibility	No. of projects
$BCR \geq 1$	$AHP \geq 0.5$	Retention	318 (44.7%)
$BCR \geq 1$	$AHP < 0.5$	Reversal (Offset)	6 (0.8%)
$BCR < 1$	$AHP \geq 0.5$	Reversal (Supplement)	128 (18.0%)
$BCR < 1$	$AHP < 0.5$	Retention	260 (36.5%)
Total			712 (100%)

Note: Cases include 696 PFSs (including scenarios) in which the AHP evaluations were carried out during 1999-2018.

TABLE 8—CONDITIONAL PROBABILITY OF CHANGE IN FEASIBILITY

Change in feasibility	Independent event	Dependent event	No. of outcomes	Conditional probability
Retention	$BCR \geq 1$	$AHP \geq 0.5$	318	0.9815
Reversal (Offset)	$BCR \geq 1$	$AHP < 0.5$	6	0.0185
Reversal (Supplement)	$BCR < 1$	$AHP \geq 0.5$	128	0.3299
Retention	$BCR < 1$	$AHP < 0.5$	260	0.6701

Note: Cases include 696 PFSs (including scenarios) in which the AHP evaluations were carried out during 1999–2018.

Feasibility reversal cases can be divided into two categories. If economic feasibility is secured but overall feasibility is not secured ( $BCR \geq 1$  and  $AHP < 0.5$ ), it can be said that the secured economic feasibility based on efficiency is “offset.” The opposite case ( $BCR < 1$  and  $AHP \geq 0.5$ ) is termed the feasibility “supplement” case. What is interesting here is that when feasibility reversal occurs, there are approximately 21.3 times more feasibility supplement cases than feasibility offset cases. That is, there is very large asymmetry with regard to feasibility reversals.

To look at this more closely, we used the conditional probability to obtain the results shown in Table 8. In other words, when economic feasibility is considered as an independent event and overall feasibility is deemed as a dependent event, when economic feasibility is secured, the probability that overall feasibility will also be secured is 98.15 percent, and, conversely, the probability that feasibility will be offset is only 1.85 percent. In contrast, if economic feasibility is not secured, the probability of the occurrence of feasibility supplementation with overall feasibility is relatively high at 32.99 percent.

Although the cause of this asymmetry is not clear and a more in-depth investigation is necessary, we can conjecture two possible reasons. First, this may be caused by the systematic method used, in which the results of BRD analysis are reflected in the comprehensive evaluation. In the comprehensive evaluation using AHP, a transformation formula is used to match the RBI to the unit of the AHP scores. This standard score conversion formula is composed of polynomials of regional backwardness rankings by city and county ( $LIR$ ) and rankings by metropolitan city and province ( $MIR$ ), as

$$\alpha + i$$

where

$$\alpha = 0.81220 + 2.23298 \times LIR - 0.29626 \times LIR^2 + 0.74302 \times LIR^3 + 0.32728 \times MIR^2$$

and

$$i = \begin{cases} 1 & \text{if } \alpha \geq 1, \\ -1 & \text{otherwise} \end{cases}$$

(KDI, 2008, p.174). From this formula, we find that the lower the ranking (the greater the value of *LIR*) is, the more the standard score is reflected, relative to linearity, if the ranking of the regional backwardness is lower than an area ranked as average. Therefore, the formula is structured to assign additional points to severely underdeveloped areas in a marginally increasing manner, which may be advantageous with regard to feasibility supplement. However, the structure of AHP scoring is not linear with respect to the scale in pairwise comparisons and cannot therefore be determined until a closer examination is conducted. Such a review is outside of the scope of this study and will be left as a future research project.

Second, the psychological factor of the AHP evaluator may have played a role during the comprehensive evaluation. In other words, if economic feasibility is not secured when the location of the project is underdeveloped, there is a possibility that the AHP evaluator assigns a relatively low weight to the economic analysis taking into account CBA limitations, such as the limited benefit estimated from the low demand forecasted in an underdeveloped area. In this case, underdeveloped areas are given extra points by the BRD analysis, and the influence of the additional points can be greater when the BRD analysis is assigned a greater weight. In the opposite case, even if the project is planned to be implemented in a developed area, it can be burdensome for the AHP evaluator to consider the equity as high so as to oppose the implementation of the project in the context of economic feasibility as a result of the CBA based on scientific methodology. This conjecture also requires a closer analysis and review for verification after collecting proper data and is thus also left as future work.

Meanwhile, among the feasibility reversal cases, we examined the differences according to CBA results in 128 feasibility supplement cases that showed higher frequencies than the offsets. Figure 3 shows the distribution of the CBA results of these cases. At this time, the proportions of cases for which economic feasibility were not secured but those with  $BCR \geq 0.9$  and  $BCR \geq 0.8$  were found to be 55.5 percent and 78.1 percent, respectively. All such cases for which  $BCR < 0.6$  were

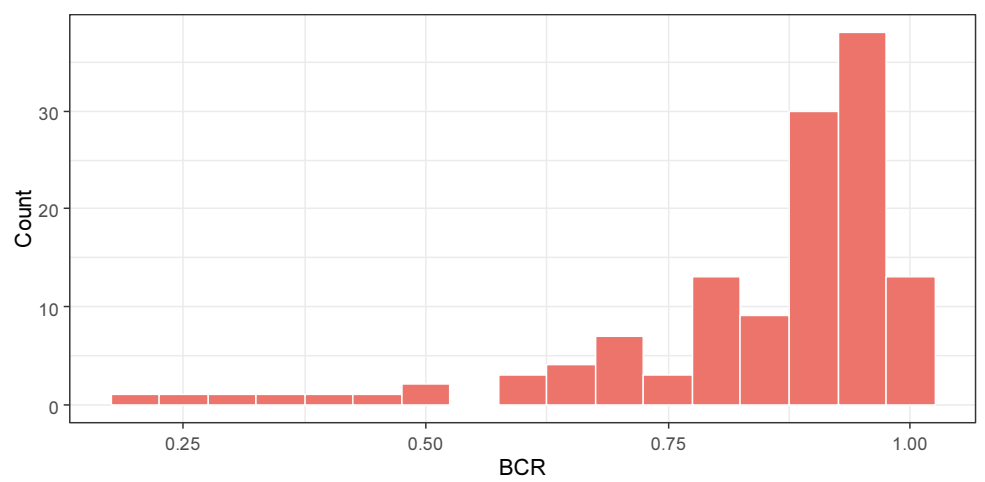


FIGURE 3. DISTRIBUTION OF CBA RESULTS IN FEASIBILITY SUPPLEMENT CASES

Note: Cases include 696 PFSs (including scenarios) in which AHP evaluations were carried out during 1999-2018.

completed before 2006, the year in which the BRD analysis was upgraded to the first tier. As can be intuitively expected, feasibility supplement was effective as the project approaches economic feasibility (i.e., as the BCR moves closer to 1 from below this value). In addition, it can be seen that the frequency of the occurrence of feasibility reversal decreases rapidly as the project moves away from economic feasibility (i.e., as the BCR decreases).

Lastly, in order to determine how changes in the pre-weight of the BRD analysis affected the occurrence of feasibility reversal, the ratio of feasibility reversal among all projects by year was divided into feasibility supplements and offsets. These results are reported in Figure 4, in which the solid line represents the mid-point value of the allowed range of pre-weights of the BRD analysis in the overall evaluation. After 2006, when the BRD analysis was upgraded to the first tier in the AHP structure, feasibility offset did not occur, except in 2006 and 2009, and the feasibility offset ratios for these years were less than 4 percent. In addition, it should be noted that the feasibility supplement ratio revealed a declining trend since 2006 despite the increase in the mid-point value of the pre-weight range of the BRD analysis. More precisely, the feasibility supplement ratio and the mid-point of the pre-weight range of the BRD analysis had an inverse correlation, as the correlation coefficient obtained was -0.244. Considering the increasing trend of the actual weight for the BRD analysis as confirmed in Table 5 and Table 6, we can expect that the likelihood of feasibility supplement will increase as the pre-weight of the BRD analysis becomes adjusted upward, as shown in Figure 1. Counterintuitively, such a uniform effect has not been largely expressed in reality. Due to the different characteristics of each project, available data cannot accurately identify the cause of this outcome. Nevertheless, from the above results, we can infer that the method of increasing the pre-weight of the BRD analysis over the past, for instance, ten years did not significantly improve the issue of equity impairment. This is indicated above as a limitation of the CBA.

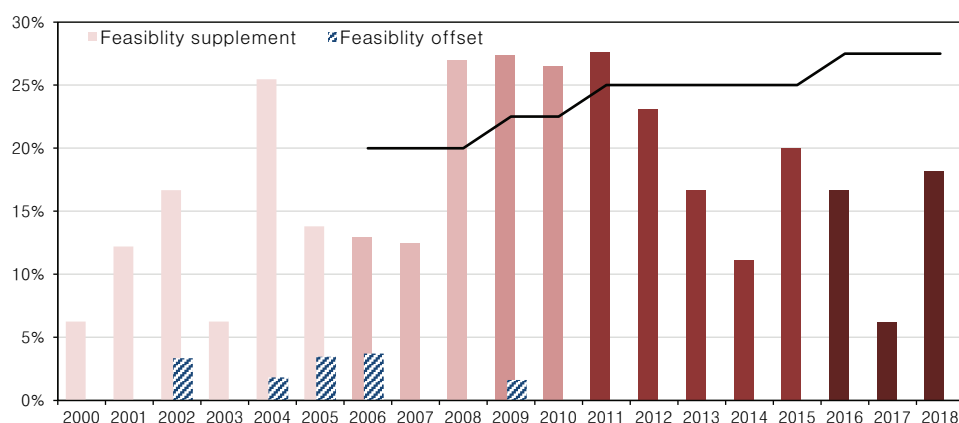


FIGURE 4. RATIO OF FEASIBILITY REVERSAL BY YEAR

Note: 1) Cases include 696 PFSs (including scenarios) in which the AHP evaluations were carried out during 1999-2018, 2) The bars representing the feasibility supplements are categorized by their colors to distinguish the periods divided in Figure 1, 3) The solid line represents the mid-point value of the allowed range of pre-weight of the BRD analysis in the overall evaluation.



However, care must be taken not to misinterpret the result of this weak improvement. This result should not be misunderstood as the economic feasibility of the project to be implemented in the underdeveloped area being very poor, and even if the weight to the BRD analysis was increased, it would remain insufficient to supplement the feasibility. In contrast, in such a case, all other things being equal during the period of 2006-2018, the proportion of the feasibility supplement should increase as the weight to the BRD analysis increases. Therefore, such a result suggests that there is no persistent relationship between the outcomes of economic and BRD analyses.

Due to data limitations, it was not possible to carry out a detailed analysis of these contentions, but we can conjecture that a “learning effect” has arisen in the planning process of the line ministry since 2006. As a result, it is possible that the economic feasibility has gradually improved. As the PFS system was institutionalized, the level of effort and preparation by line ministries may have generally increased in the conception and planning stages of the project, thereby increasing the economic feasibility of the project (i.e., expanding the benefits compared to the costs). In such a case, even if an attempt is made to lower the weight of the judgment based on efficiency standards by increasing the pre-weight of the BRD analysis based on equity, the probability of feasibility supplementation may decrease as the economic feasibility results gradually improve.

For a better understanding of this, Figure 5 summarizes the CBA results (BCRs) by year, where the line and shaded area represent the annual average and range of the BCRs, respectively. The data include 448 out of the total 449 PFSs carried out during 2006-2018, excluding an outlier in 2006 where the BCR was exceptionally high. From this figure, two major observations can be made. First, it shows that the average of the CBA results is maintained without much change at around 1 throughout the data period of 2006-2018. To examine this finding more closely, we tested whether there are differences in the CBA results by year and found no statistically significant differences. In view of this, the tendency for the BCR to increase over time during the period of 2006-2018 is not confirmed.

Second, although the scope of the CBA results differs from year to year, it can be seen that the maximum BCR value for each year increased compared to those of the previous years. This is particularly true after 2017. In addition, as a result of the CBA, the proportion of the total in which economic feasibility is secured (ratio of  $BCR \geq 1$ ) is plotted by year in Figure 6. This figure shows that the proportion tends to gradually increase over time in a manner similar to that seen in Figure 5. As a result of a simple regression analysis of the proportion to the year, it was found that the proportion of cases securing economic feasibility increased by 0.85 percent each year during 2006-2018, with this result statistically significant at the 1 percent significance level. Note that the result does not mean that the economic feasibility of individual projects becomes higher over time but rather that the proportion of projects evaluated as economically feasible for each year increases. Therefore, these results should not be misinterpreted as the probability of securing economic feasibility of individual projects, and it should be noted that the probability is independent of the passage of time, as discussed above.

Moreover, the results obtained, as shown in Figure 5 and Figure 6, confirm that the learning effect of line ministries described above is being expressed to some

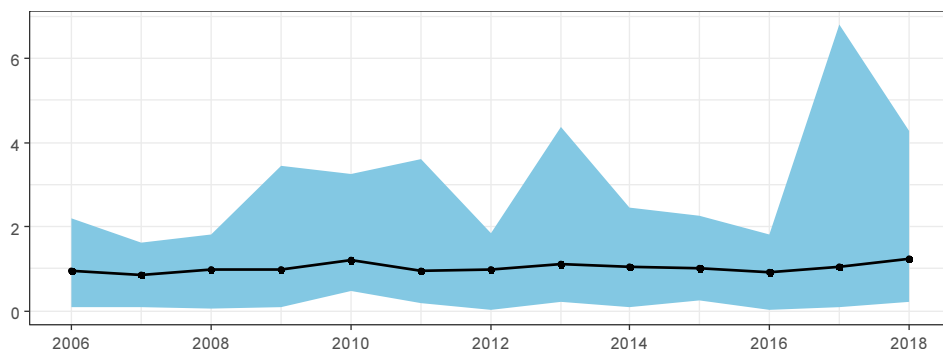
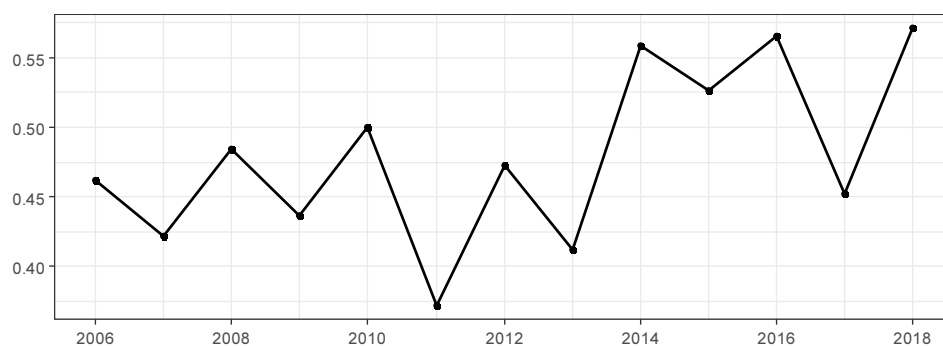


FIGURE 5. BENEFIT-TO-COST RATIO BY YEAR

Note: 1) Cases include 448 PFSSs (including scenarios) carried out during 2006-2018, excluding an outlier in 2006, 2) The solid line and shaded area represent the annual average and range of BCRs, respectively.

FIGURE 6. PROPORTION OF PFSSs SECURING ECONOMIC FEASIBILITY (BCR  $\geq 1$ )

Note: Cases include 449 PFSSs (including scenarios) carried out during 2006-2018.

extent. In other words, the probability that the economic feasibility of the project is secured does not change from year to year, but as time passes, the proportion of projects with high BCR planned increased and thus the economic feasibility by year also tended to increase. From the perspective of feasibility reversal, as shown in Figure 3, feasibility supplement was effective when the BCR was close to 1; thus, what is left is to determine the difference by year for these cases. For convenience of the discussion, a project in which economic feasibility is not secured but whose BCR is close to 1 will be referred to as a “marginally economically feasible project” (MEFP). The lower bound, i.e., the least amount of BCR of the project that should be the cut-off standard in order to be an MEFP project, is unclear. Therefore, referring to the results in Figure 3, we will take into account projects with BCR values greater than or equal to 0.7, 0.8, or 0.9 but less than 1. Within these standards, the proportion of feasibility supplement by year and three ratios of MEFPs according to the different definitions above are plotted in Figure 7.

In all cases with the three MEFP criteria, the proportion of MEFPs is similar to that of the feasibility supplement by year, especially when  $0.7 \leq \text{BCR} < 1$ . In addition,

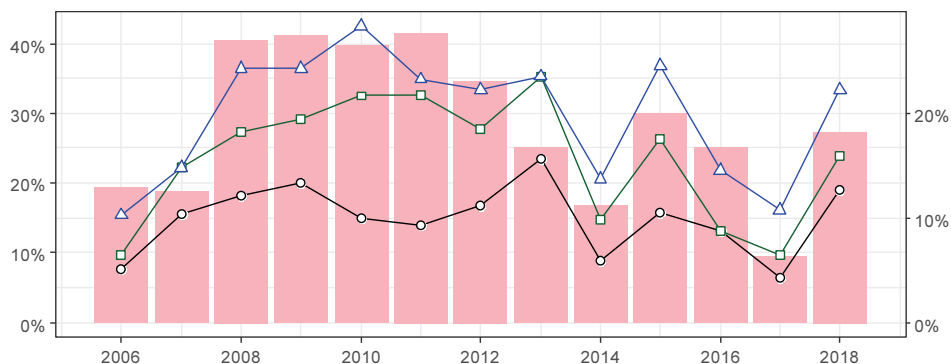


FIGURE 7. PROPORTION OF FEASIBILITY SUPPLEMENT AND MARGINALLY ECONOMICALLY FEASIBLE PROJECTS BY YEAR

Note: Cases include 449 PFSs (including scenarios) carried out during 2006-2018.

the proportion of feasibility supplement by year and the ratio of MEFPs showed very high positive interdependence with correlation coefficients of 0.855, 0.768, and 0.582 for standards of BCR greater than or equal to 0.7, 0.8, and 0.9, respectively.

Summarizing the above findings, we can conclude that the weight to the BRD analysis has gradually increased over time since 2006, whereas the proportion of feasibility supplementation has decreased. Moreover, this result occurred because the proportion of MEFPs decreased.

### C. Contribution of the Regional Backwardness Analysis

Subsequently, we determine the degree to which the regional backwardness analysis, as one of two elements of the BRD analysis, has contributed to the comprehensive evaluation. To this end, we examined the effect of the regional backwardness rankings in the area where the project in question is to be implemented considering the overall evaluation process and results. Moreover, we targeted a sample because it was not possible to gather evaluator-level information of all projects studied in the past 20 years due to the vastness of the data and time constraints. We therefore selected 237 projects with identified regions among 247 projects commissioned in 2005-2010 for the PFS.

Figure 8 reports the proportion of the BRD analyses classified with the regional backwardness ranking. Municipalities (i.e., cities and counties) are ordered by their regional backwardness ranking, and each third of them grouped and divided correspondingly into upper (developed), middle, and lower (underdeveloped) regions. The proportion of the BRD analysis is higher in areas in which the project site is located in the lower regions. Quantitatively, the weight of the BRD analysis was found to be 1.2 percent points higher in the middle regions than in the upper regions and the 1.4 percent points higher in the lower regions than in the middle regions. More precisely, the weight of the BRD analysis in lower regions shows a statistically significant difference from those in the other regions while the difference between those in upper and middle regions are not statistically significant from the results of two sample t-tests of the equality of the weights.

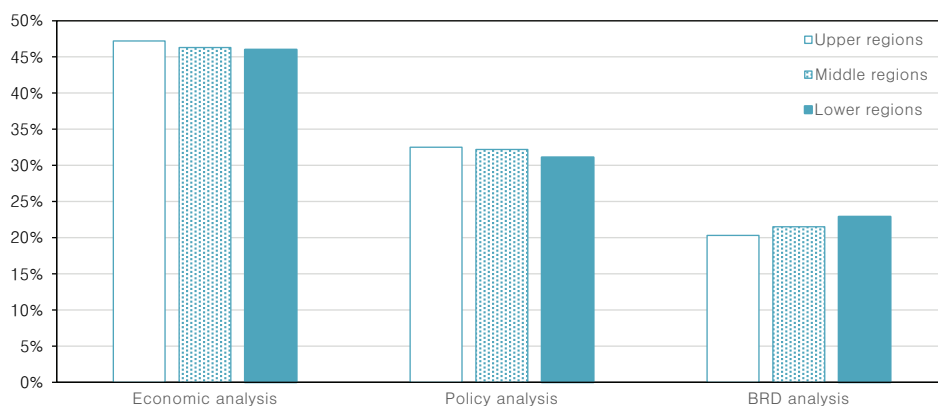


FIGURE 8. REGIONAL BACKWARDNESS RANKING AND SHARE OF FIRST-TIER EVALUATION COMPONENTS IN THE ANALYTIC HIERARCHY PROCESS

*Note:* Cases include region-specified 237 out of 247 PFSs (including scenarios) carried out during 2005-2010.

The result suggests that evaluators using AHP for comprehensive evaluations tend to consider BRD actively based on equity in less developed regions, which is in line with the asymmetry of the feasibility reversal. This occurs because if the project site is in a relatively developed region, a penalty is given in the BRD analysis during the comprehensive evaluation. Hence, if the proportion of the BRD analysis in the developed area is high, the probability of feasibility offset will increase. It is encouraging that the practice has met the purpose of introducing the BRD analysis, as it accounts for a larger portion of the overall evaluation when the region is less developed.

Moreover, Figure 8 shows that the increase in the weight of the BRD analysis for underdeveloped regions in the comprehensive evaluation reduces both the weights of the economic and policy analyses. On average, the BRD analysis proportion increased by 1.2 percent points in the middle regions compared to the upper regions. Simultaneously, the economic analysis and policy analysis showed decreased values by 0.9 percent points and 0.3 percent points, respectively. In addition, the BRD analysis proportion increased by 1.4 percent points in the lower regions compared to the middle regions, while the corresponding ratio of economic analysis and policy analysis decreased by 0.3 percent points and 1.1 percent points. Compared to the upper and lower regions, the BRD analysis proportion increased by 2.6 percent points and the economic analysis and policy analysis proportion decreased similarly to each other (-1.2 percent points and -1.4 percent point, respectively). As a result, it was confirmed that the trade-off between equity and efficiency was mainly considered between the upper and middle regions, but not between the upper or middle regions and the lower regions. This suggests that improvement is needed to focus on the trade-off between equity and efficiency in line with the purpose of introducing the BRD analysis in the future.

Lastly, the ratio of securing overall feasibility according to the ranking of regional backwardness is shown in Figure 9. This figure divides projects according to economic feasibility: a group for which economic feasibility is secured ( $BCR \geq 1$ ),

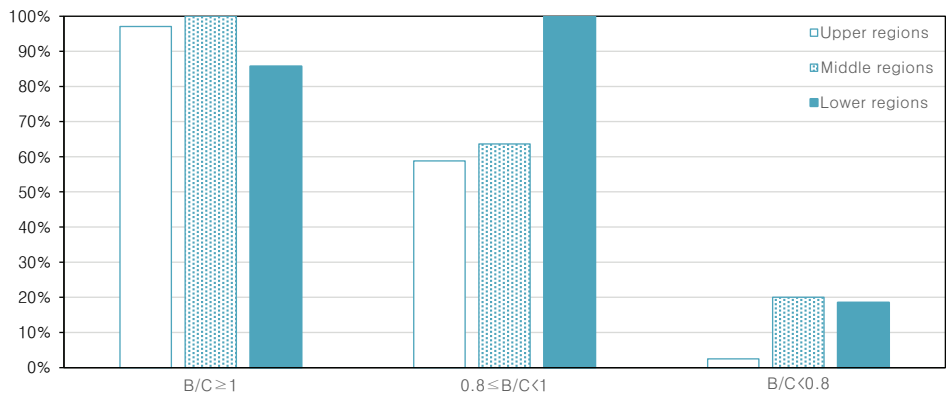


FIGURE 9. REGIONAL BACKWARDNESS RANKING AND PROPORTION OF OVERALL FEASIBILITY

Note: Cases include region-specified 237 out of 247 PFSs (including scenarios) carried out during 2005-2010.

the MEFP group ( $0.8 \leq BCR < 1$ ), and a group lacking economic feasibility ( $BCR < 0.8$ ). Two sample t-tests for equal proportions of overall feasibility reveal that the differences between all proportions within regions and groups categorized by economic feasibility are statistically significant at the 1 percent significance level, except for the difference between the MEFP group and the group lacking economic feasibility in the lower group.

As economic feasibility falls in the upper and middle regions, the ratio of securing overall feasibility also decreases. In the lower regions, however, the ratio of securing economic feasibility was highest in the MEFP group, followed by the group that secured economic feasibility and the group which lacked economic feasibility. For each project group, in groups with and without economic feasibility, the ratio of securing overall feasibility in the middle regions was highest, whereas in the MEFP group, lower regions' proportion of securing overall feasibility was remarkably higher than those of the other two regions. It should also be noted that the ratio of securing overall feasibility of the upper regions is low, with a large gap, in the group that lacks economic feasibility. It is difficult to make a direct and clear comparison due to the different characteristics of each project. However, this outcome is intuitive because when economic feasibility of the project is largely lacking and the project is promoted to the upper region, its evaluation result is deducted further from the BRD analysis. For cases with  $BCR \geq 0.8$ , it can be said that the reflection of regional backwardness is effective for the MEFP group ( $0.8 \leq BCR < 1$ ). This is again in line with the purpose of introducing the BRD analysis to overcome the limitations of the CBA.

IV. Policy Implications and Suggestions

A. Policy Implications

This study aimed to investigate the effects of the BRD analysis in PFSs. To this end, it focused on three aspects; (a) whether the policy intention was effectively

fulfilled at the actual stage of the PFS, (b) whether the consideration of BRD influenced the actual results according to the trade-off between equity and efficiency, and (c) whether the consideration of equity in less developed regions was actually reflected to a large extent.

First, with reference to the effective fulfillment of the policy intention, it was confirmed that the actual weight given by AHP evaluators was raised according to the change in the situation where the pre-weight of the BRD analysis in the PFS was steadily increased. Therefore, through the introduction of the BRD analysis, the policy intention to give more consideration to equity was effectively realized.

Second, by examining the different forms of feasibility reversal, we analyzed the changes in the evaluation results according to the efficiency criteria by considering equity in relation to the equity-efficiency trade-off. Interestingly, the case of feasibility supplementation, in which overall feasibility is secured although economic feasibility is not, accounted for a very high proportion compared to the opposite case, i.e., the feasibility offset case. Possible reasons are that the structure of AHP used for the comprehensive evaluation may be a structure that is advantageous for feasibility supplementation or that the psychological factors of the AHP evaluators may have played a role. However, more in-depth studies will be needed to confirm these conjectures.

In addition, feasibility supplementation occurred more frequently when the project was closer to the threshold of economic feasibility ( $BCR = 1$ ), as expected. This is encouraging in that the introduction of the BRD analysis resulted in the intended effective equity-efficiency trade-off.

However, we found that the overall feasibility supplement ratio by year decreased over time despite the increase in the magnitude of the pre-weight of the BRD analysis. This is not intuitive at first glance when taking into account the purpose of raising the pre-weight of the BRD analysis, but this result can be explained by the fact that the proportion of MEFPs was decreasing. As described above, feasibility supplementation frequently occurs for MEFPs. As the proportion of MEFPs becomes smaller, the feasibility supplement ratio decreases.

Meanwhile, AHP evaluators on average lowered the weights of both economic and policy analyses while they increased the weight to the BRD analysis. This suggests that it is necessary to improve the system in a way that focuses more specifically on the equity-efficiency trade-off. In this way, weight adjustments between an economic analysis and a BRD analysis can occur effectively with less interference of the weight to the policy analysis.

Third, as a result of examining how the contribution of the BRD analysis varies depending on the development level of the target region of the project, the BRD analysis results were more actively reflected in less developed areas, in accordance with the policy objective. Moreover, for MEFPs in particular, the BRD analysis appeared to help increase the possibility of securing overall feasibility, as the proportions of securing overall feasibility among MEFPs were in the reverse order of development.

In conclusion, the BRD analysis has played a significant role in the course of conducting PFSs over the past 20 years, and our results were mostly in line with the policy objective and background to take into account equity among regions and to increase its weight in public investment decisions. However, because the system has

been implemented in a different way since 2019, the results of this analysis have implications for future applications of the system.

The change in the PFS process that occurred in 2019 led to a differentiation between SMA and non-SMAs when considering BRD. The BRD analysis is not included in the PFS of projects to be implemented in the SMA, and the pre-weight of the BRD analysis in the PFS for non-SMAs has been increased to 30-40 percent. In addition, the comprehensive evaluation using the AHP is carried out by the PFS Committee, which is composed of private experts and installed under the Ministry of the Economy and Finance. From the perspective of the analysis, this change has resulted in the exclusion of the analysts who conducted the PFS from the AHP evaluation. The analysts participated in the AHP evaluation because they have a high level of understanding and expertise in relation to the project in question. Under the new system, a disadvantage is that the understanding of the project in question is relatively low and the accuracy of the comprehensive judgment may be limited due to the lack of expertise. Nevertheless, a positive aspect of the change is that it conforms to the general principle that the budget process is a political process and that analysts do not make (political) decisions (Boardman *et al.*, 2011, p.15).

Rather than discussing whether the changes in the system were positive or negative, we present a standard by which to measure how the contribution of the BRD analysis will change in future comprehensive evaluations as a result of the changes. Before the institutional change in 2019, the evaluators participated in the AHP evaluations after already knowing the results of all of the evaluation components. Under the new scheme, they assess the feasibility with respect to policy aspects in AHP evaluations without knowing the results of the economic analysis, and this is reflected exogenously afterward. Previously, Table 8 revealed the conditional probabilities according to the current comprehensive evaluation scheme. Thus, in line with the changed procedures, we can consider the conditional probabilities in which the comprehensive evaluation result is an independent event and the economic analysis result is the dependent event. Table 9 shows the results of the analysis of such conditional probabilities according to Bayes' theorem.

According to the previous scheme, the probability that economic feasibility is also present is 71.3 percent when overall feasibility is secured. In contrast, in the absence of overall feasibility, the probability that economic feasibility is also absent is 97.7 percent. In the case of feasibility reversal, the probability of the occurrence

TABLE 9—CONDITIONAL PROBABILITY OF CHANGE IN FEASIBILITY TO BE COMPARED UNDER THE NEW COMPREHENSIVE EVALUATION SCHEME

Independent event	Dependent event	Change in feasibility	No. of outcomes	Conditional probability
$AHP \geq 0.5$	$BCR \geq 1$	Retention	318	0.7130
$AHP \geq 0.5$	$BCR < 1$	Reversal (Supplement)	128	0.2870
$AHP < 0.5$	$BCR \geq 1$	Reversal (Offset)	6	0.0226
$AHP < 0.5$	$BCR < 1$	Retention	260	0.9774

Note: Cases include 696 PFSs (including scenarios) in which the AHP evaluations were carried out during 1999-2018.

of feasibility supplementation is 28.7 percent, whereas that of feasibility offset is only 2.3 percent. As discussed above, it is appropriate to use the conditional probabilities in Table 9 to compare the outcomes under the new scheme with those under the previous scheme when a sufficient amount of data is accumulated from the implementation of the changed system in the future. Through this, it will be possible to determine if the implementation of the changed system can more effectively achieve the desired policy goal.

### *B. Policy Suggestions*

Summarizing the results of the analysis and discussions in this study, several suggestions are given below to improve the PFS system. First, there are a few aspects that require attention given how the application of the BRD analysis has changed in the overall judgment. It is necessary to accumulate the information obtained through the implementation of the new scheme for assigning points to non-SMAs and then to derive future improvements accordingly. This is important because there is a possibility that a different pattern will be realized with respect to the results of the application of the previous scheme in this study.

It is also necessary to remove the unnecessary “strategic bias” of evaluators by considering the psychological factors of the AHP evaluators in the overall judgment. If the project is promoted in a non-SMA, an evaluator who does not know the quantitative results of the economic analysis may behave strategically in two opposite directions. On the one hand, because the evaluator knows that the project is being promoted in a non-SMA, it is possible to increase the weight of the BRD analysis. The evaluator can accept the differentiated treatment between SMA and non-SMA cases as a signal to take a favorable position regarding the promotion of the project in a non-SMA from the perspective of BRD, even if it is economically infeasible. Accordingly, if the evaluator makes a qualitative judgement that the economic feasibility of the project is insufficient, she can respond with the feasibility supplement in mind to make up for it.

On the other hand, because the evaluators do not know quantitative results of the economic analysis, they can lower the weight of the BRD analysis to avoid a burden that causes a feasibility reversal outcome. It is critical to eliminate such bias, as the overall judgment requires the assignment of reasonable weights from an expert point of view by synthesizing the characteristics of the project and various results of the analysis.

Second, efforts are needed to tackle issues with the regional economic ripple effect analysis. As discussed in Section 2, the current regional economic ripple effect analysis contains both the limitations of the input-output (IO) model, in which the IRIO model is nested, and the GRDP. The problem with the IO model is that only positive effects are reflected linearly as a ripple effect. In other words, negative effects of the project are not reflected, and when the size of the project is doubled, the ripple effect is estimated to be exactly doubled. In addition, it has been pointed out that the GRDP has problems of representation and adequacy as an indicator of the economic power in the region. For example, for a company with production bases in various regions, the final production result may all be assigned to the region in which the head office is located, and there may be differences due to inconsistencies



between the production location and the workers' residences.

As long as the current methodology is maintained, fundamental improvements may be difficult due to the above-mentioned limitations. Therefore, efforts will need to be made further to identify both positive and negative effects centered on the relevant sector of the project being promoted. As an outcome-oriented approach, it will be possible to examine the gap between the national average and the level of the development of the region in which the project is being targeted, and how the implementation of the project can help to close this gap.

In addition, the current regional economic ripple effect is concentrated on the effect during the construction period. It is necessary to expand this period to include the effect of the entire operation period as much as possible, although understanding this effect can be very challenging due to various uncertainties.

In particular, if the CBA method is not directly related to demand estimates, it is necessary to review the regional impact in the BRD analysis carefully. For example, when estimating the benefits by applying the WTP elicitation method via a survey, such as via the contingent valuation method in the CBA, the calculation of the benefits is not directly linked to the estimate of demand.

Third, it is possible to consider how to integrate the policy analysis and BRD analysis into what is termed a "social value analysis" in the mid- to long-term period. In this way, there can be an improvement in the system in which decisions are made that considers the balance between economic value based on the CBA and social value that encompasses other aspects. In the United Kingdom, through the enactment of the Social Value Act, considering additional benefits by reflecting social values (economic, social, and environmental) during public procurement efforts is obligatory. If the BRD is an important social value, as stated in Article 123 of the Constitution of the Republic of Korea, it will be worth reviewing the change in the system in such a direction.

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# Robust Contract Conditions Under the Newly Introduced BTO-rs Scheme: Application to an Urban Railway Project<sup>†</sup>

By KANGSOO KIM<sup>\*</sup>

*Few studies have specifically focused on the uncertainty of demand forecasting despite the fact that uncertainty is the one of greatest risks for governments and private partners in PPP projects. This study presents a methodology for finding robust contract conditions considering uncertainty in travel demand forecasting in a PPP project. Through a case study of an urban railway PPP project in Korea, this study uncovered the risk of excessive government payments to private partners due to the uncertainty in contracted forecast ridership levels. The results allow the suggestion that robust contract conditions could reduce the expected total level of government payments and lower user fees while maintaining profitability of the project. This study offers a framework that assists contract negotiators and gives them more information regarding financial risks and vulnerabilities and helps them to quantify the likelihood of these vulnerabilities coming into play during PPP projects.*

Key Word: PPP, BTO-rs, Contract Conditions, Robustness,  
Uncertainty, Forecast, Ridership  
JEL Code: R42, R40

## I. Introduction

The Korean government started in 1994 to push Public Private Partnership (PPP) projects to encourage private participation in infrastructure investments. By providing various forms of government support, and the PPP model has emerged as a well-established procurement method for many types of infrastructure and public facilities.

Despite such positive aspects, however, PPP projects in Korea face criticism due to unexpected hikes in the government's payments to private partners through the

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minimum revenue guarantee (MRG) scheme<sup>1</sup> as well as high user fees. Numerous projects, including the Incheon International Airport Expressway and the Nonsan–Cheonan Expressway, have shown that actual out-turn traffic volumes were far below than the contracted traffic agreed-on levels in concession agreements, resulting in higher government payments. In addition, road PPP projects such as the Seoul Ring Expressway are meeting resistance from users due to fees higher than those of publicly financed projects.

Accordingly, the Korean government had made strong efforts to reduce its financial burden and lower user fees by extending concession periods, sharing refinancing gains, and changing the contract conditions through renegotiations with private investors. In particular, the Korean government introduced a risk-sharing scheme for built-transfer-operation (BTO)<sup>2</sup> projects in 2015 to low high user fees by reducing private partners' project risk and to reinvigorate the modality, i.e., the BTO risk-sharing project scheme (BTO-rs).

Even with the BTO-rs scheme, contracted forecasting demand levels for facilities also become one of the most important contract conditions between the government and private partners because unexpected hikes in government payments and user fees are closely linked to the inadequacy in dealing with uncertainty in contracted forecasting demand levels. As the level of contracted demand for a facility increases, the operating income also increases, and this can lower the construction cost subsidy, the level of investment cost sharing by government, and the user fees related to the project. In addition, the lower the contracted demand for the facility is, the higher the government's construction cost subsidy and investment cost sharing levels become, with a higher level of user fees also arising. Therefore, contracted forecasting demand is the one of most salient risks for the government and private partners when implementing a PPP project. Despite this concern, simple average and aggregated point demand forecasts that ignored the potential for unexpected fluctuations have been used.

The uncertainty in travel demand forecasting is caused by factors such as uncertain input data, limitations of the predictive models used, and the characteristics of the project under analysis. There are compelling reasons for undertaking travel demand forecasting even with deep uncertainty. Travel demand forecasting is conducted through the traditional four-step model where numerous input variables, such as the population and employment rate, are predicted and where it is assumed that the predictions are correct. However, a more suitable expression would be 'properly estimated' rather than 'accurate'. Thus, as the steps progress, due to 'properly estimated' data entailing inevitable errors mitigated by inappropriate (or non-realistic) model specifications for each step, the level of uncertainty expands. Biased decisions by analysts also add uncertainty to travel demand forecasting.

To consider the uncertainty in travel demand forecasting, existing approaches assume that the distribution of traffic demand forecasting is known or the uncertainty is calculable. Accordingly, demand forecasting in PPP projects is inadequate when

<sup>1</sup>In the MRG scheme, the government guarantees the predetermined contract revenue through government payments when the actual outturn revenue falls below the contract revenue.

<sup>2</sup>In a BTO contract, the private partner builds the infrastructure, transfers ownership to the government and operates for a concession period to recoup its investment. Meanwhile, in a BTL contract, the private partner builds the infrastructure, transfers ownership to the government and recoups its investment through government payments.

dealing with the uncertainty. Simple average and aggregate point demand forecasts are applied, and negotiations do not take into account unexpected increases in government payments or bankruptcies of projects stemming from the uncertainty in the contracted forecasting demand.

The explanatory approach known as robust decision making (RDM) is a promising tool for dealing with uncertainty in travel demand forecasting. RDM, exploring acceptable policies under deep uncertainty is mainly applied to topics such as water resource management, disaster prevention, and climate change, all of which entail relatively large events with extended analysis periods. However, recently, the scope of these subjects is being expanded, with RDM now applied to various disciplines. Using RDM, it is possible to approach the travel demand forecast problem more reasonably. The RDM approach tests possible future states specified by a wide range of decision spaces, with these utilized for characterizing areas of vulnerability (Marchau *et al.*, 2019). As such, the method is readily applicable to travel demand forecasting, as unpredictability is part of the method. The framework of the RDM approach, termed the inversed ‘predict-then-act’ framework, easily finds factors that could not be identified by the existing ‘predict-then-act’ scheme. Thus, it enables more explanatory, rational and adaptive policy establishment outcomes for the future.

The purpose of this study is to apply the RDM approach to present a methodology for finding robust contract conditions<sup>3</sup> which minimize negative effects on governments and private partners considering the uncertainty in travel demand forecasting in PPP projects. In other words, this study suggests acceptable and robust BTO-rs contract conditions to ensure the best performance of a PPP project. Because this unlike forecast-then-contract approaches, this study suggests bottom-up decision making regarding the contract condition for dealing with vulnerability properly and minimizing any negative effects caused by uncertainty in demand forecasting.

The remainder of the study proceeds as follows. Chapter I presents the study’s purpose and background and Chapter II introduces the concept of uncertainty in demand forecasting and existing methods that attempt to consider uncertainty. This chapter also presents a literature review of PPP contracts assuming that the uncertainty in demand forecasting is controllable or the result of demand forecasting is accurate. Chapter III introduces the concept of the BTO-rs scheme with a schematic representation of typical cash flows. This study also involves a case study of an urban railway PPP project. Chapter IV presents the case study, currently ongoing in the Seoul Metropolitan Area (SMA) in Korea, to derive the acceptable range of BTO-rs contract conditions given uncertainty in ridership forecasting. Chapter V specifies the decision variables, objective functions and an uncertainty variable with which to conduct the RDM approach. A multi-objective function is developed to establish the interest of the government and private partner with a focus on minimizing of government’s payments (GP) and maximizing the project’s NPV, and the objective functions are optimized to derive the plausible range of contract conditions under the BTO-rs scheme.

Chapter VI presents a regret-based robustness evaluation criterion, through which

<sup>3</sup>Robust contract conditions are defined as those that minimize government payments and maximize the project’s NPV while also limiting the range of variance in the government’s payments and NPV levels in most situations.

various feasible contract conditions are evaluated and a vulnerability analysis is conducted to find robust contract conditions. Based on the analysis, Chapter VII summarizes the results of this study, presents the conclusion, and discusses limitations.

## II. Related Literature

There have been several studies of the conditions of contracts related to demand forecasting in PPP projects. However, all of them assumed that the uncertainty in demand forecasting is controllable and all were based on the 'predict-then-act' concept, the opposite of the 'bottom-up' concept, which is the basic analysis framework of RDM. These approaches start with the assumption that uncertainty is predictable and that the error specification is wide enough to represent the future. However, a fundamental problem is that if the prediction is not correct, subsequent decisions are subject to higher rates of incorrectness.

Yang and Meng (2000) analyzed optimal capacity and toll levels for PPP road projects with an 'assumed' accurate point estimate for future traffic volumes. Chen *et al.* (2003) developed a multi-objective programming model to maximize private investors' expected profits and minimize the risk of projects. They simultaneously obtained the optimal toll and capacity for a BOT-road project using a multi-objective genetic algorithm with the assumption of the traffic volume as a random variable. Tan and Yang (2012) analyzed tolls, concession periods, and government subsidies according to the degree of flexibility in a PPP project contract. They considered the uncertainty in traffic demand forecasting using observed traffic volumes but failed to reflect the future growth and volatility of the traffic volume. Feng *et al.* (2016) designed a negotiation process in a PPP project as a two-stage optimization problem and computed a government payment schedule according to toll scenarios. They showed that renegotiations occur in a BOT road contract when the investor's behavior due to loss aversion is at a sufficiently low level. However, this approach lacks consideration of the uncertainty in traffic demand forecasting. Zhang *et al.* (2018) also compared socially optimal prices of tolls, road capacities, and concession periods under a single period concession structure and a two-period concession structure of BOT PPP contracts without reflecting the uncertainty of traffic demand forecasts.

In addition, PPP contract specification problems have been studied with a rather narrow vision toward future states, as contract specifications are countable. Accordingly, the problem is often framed within a limited number of scenarios. In such studies, a binomial lattice is a preferred modeling scheme for dealing with contract specifications, as it branches all possible scenarios related to future changes with a tree structure. Similar to the binomial lattice, Bowe and Lee (2004) utilized the log-transformed binomial valuation model developed by Trigeorgis (1996) for valuing several compound options associated with a high-speed rail project in Taiwan. This binomial valuation method was further developed (Ho and Liao, 2011) by integrating fuzzy theory in order to reflect forms of flexibility in investment decisions, such as expansions, extensions, or even the abandonment of an underlying project.

As such, previous studies researched PPP contract conditions such as toll levels, road capacities and concession periods based on the simple assumption that the

uncertainty of demand forecasting is calculable and the results of demand forecasts are accurate. However, this paper considers the uncertainty of demand forecasting as incalculable.

Due to the limitations of existing studies, the PPP contract conditions associated with travel demand forecasting must be approached with RDM, which examines the existence of deep uncertainty. RDM (Lempert and Collins, 2007) identifies potential strategies, evaluates trade-offs by calculating the vulnerabilities of such strategies, and conducts adaptive decision making. Recently, Kasprzyk *et al.* (2013) proposed the method of multi-objective robust decision making (MORDM), which expands RDM to a decision-making issue featuring the functions of multiple objectives. Adopting this multi-objective function helps stakeholders navigate the space of feasible strategies and discover alternatives using optimal trade-offs. That is, unlike the 'predict-then-act' or 'top-down' approaches to policy that assume an accurate forecast, RDM is a bottom-up approach and develops contract conditions which deal with vulnerability while also minimizing any negative effects due to deep uncertainty. RDM, which tests a significant number of cases and seeks to construct scenarios using the identified vulnerabilities caused by deep uncertainties, is suitable for dealing with uncertainty in travel demand forecasting, which shows a wide range of change, even from day to day.

### III. Built-Transfer-Operation (BTO)-rs scheme

The Korean government had been striving to reduce its financial burden and lower user fees, and it introduced a risk-sharing scheme for built-transfer-operation (BTO) projects in 2015. In the BTO scheme, investment and operating risks belong to the private partner; however, the investment and operating risks are shared by the government and the private partner at a certain ratio, and both share excess profits or losses under the BTO risk-sharing (BTO-rs) scheme.

If the share of the investment costs between the government and the private partner is evenly split, the private partner can receive a certain portion of the operating costs from the government when demand for the infrastructure facility or service is not sufficient. However, when demand exceeds the contracted forecast, the government receives a partial return of the private partner's profits. Because the government shares a portion of the private sector's investment risk, the rate of return of the private partner's investment is reduced, ultimately lowering user fees associated with the project as well.

Figure 1 presents a schematic explanation of the cash flow under the BTO-rs scheme. As shown in the figure, important contract conditions in the BTO-rs scheme are the ratio of investment cost sharing by the government to the total private investment ( $p_2$ ), the ratio of excess profits or losses shared by the government to the operational profits or losses ( $\psi$ ), the ratio of the construction subsidy toward the total project cost ( $x_1$ ), the level of user fees ( $P$ ), and ridership for operational year  $i$  ( $K_i$ ). When  $p_2$  and  $\psi$  are both zero, there is no government risk sharing for private investment, meaning that this situation is identical to the BTO scheme,

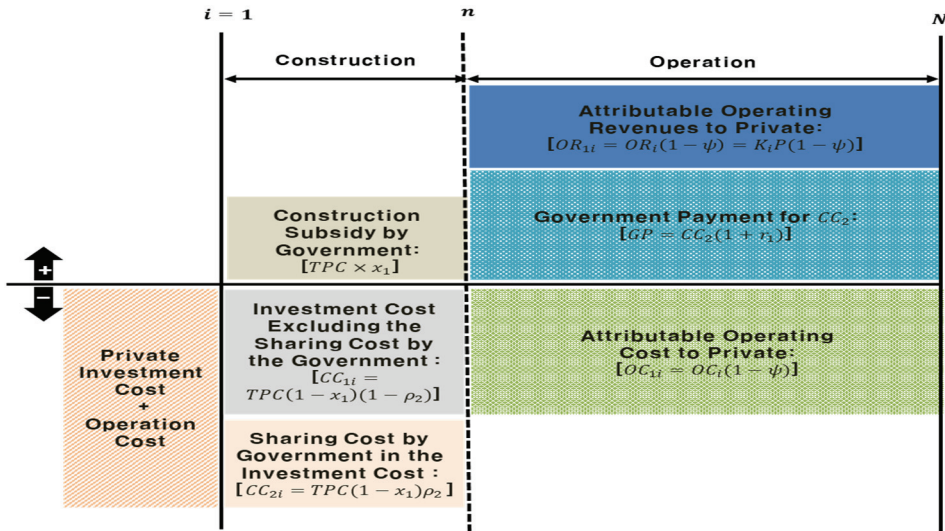


FIGURE 1. CASH FLOW OF THE BTO-RS SCHEME

where only a construction subsidy exists.

There is a construction subsidy for cash-in during the construction period (from 1 through  $n$ ), and the construction subsidy by the government can be expressed as the total project cost ( $TPC$ ) of the project multiplied by the ratio of the construction subsidy ( $x_1$ ). Additionally, there are two items for cash outflows during the construction period in the BTO-rs scheme; these are related to the private partner's investment cost. The first is the private partner's investment cost excluding the shared investment cost by the government ( $CC_1$ ), and the second is the shared investment cost by the government as part of the private partner's investment cost ( $CC_2$ ). Here, the  $CC_1$  can be converted as  $CC_1 = TPC(1 - x_1)(1 - p_2)$  and  $CC_2$  can be determined from the total project cost ( $TPC$ ) excluding the government's construction subsidy multiplied by the ratio of investment cost sharing by the government to the total private investment cost ( $p_2$ ),  $CC_2 = TPC(1 - x_1)p_2$ .

During the operational period (from  $n+1$  through  $N$ ), the cash inflow contains two items: the government's payment ( $GP$ ) for the shared cost by the government among the private partner's investment ( $CC_2$ )<sup>4</sup> and the operating revenue attributable to the private partner ( $OR_1$ ). Here, the government's payment ( $GP$ ) can be calculated by  $GP = CC_2 \times (1 + r_1)$ , where  $r_1$  denotes the private partner's expected rate of return for the  $CC_2$ . In addition,  $OR_1$  can be expressed as  $OR_1 = OR(1 - \psi) = K \times P \times (1 - \psi)$ , where  $OR$  indicates the operating revenue. The cash outflow during the operational period ( $N - n$ ) is the operating cost borne by the private partner ( $OC_1$ ).  $OC_1$  can be expressed as the operating cost of the

<sup>4</sup>Cash inflow in the BTO-rs scheme is similar to the structure of the BTL scheme, which recovers its investment through government payments. In this respect, the BTO-rs scheme is referred to as a hybrid BTO and BTL scheme.



project ( $OC$ ) multiplied by one minus the ratio of excess losses shared by the government to the operational losses ( $\psi$ ),  $OC_i = OC(1 - \psi)$ .

Therefore, the government's payment during operational year  $i$ ,  $GP_i$ , can be expressed through the following function and is paid annually to private investors.

$$(1) \quad GP_i(x_1, p_2, r_1, \psi, P, K_i) = \frac{TPC(1 - x_1)p_2r_1}{1 - (1 + r_1)^{-(N-n)}} - \psi(K_iP - OC_i)$$

Here,  $K_i$  is the contracted ridership forecast and  $OC_i$  is the operating cost for operational year  $i$ .

Under the BTO-rs scheme, the government's payment during operational year  $i$  ( $GP_i$ ) occurs when the risk sharing base amount ( $GC_i$ ) for year  $i$  exceeds the attributable operating revenue to the government ( $OR_{2i}$ ) for year  $i$ . However, when  $OR_{2i}$  exceeds  $GC_i$ , there will be a reimbursement to the government corresponding to the difference for operational year  $i$ . Therefore,  $GC_i$  is the base amount that determines whether the government pays or is reimbursed during year  $i$ .

$GP_i$  and  $GC_i$  can be specified as follows:

$$(2) \quad GP_i = GC_i - OR_{2i} = GC_i - \psi OR_i = GC_i - \psi K_i P$$

$$(3) \quad \begin{aligned} \text{where } GC_i &= CC_2 \frac{r_1}{1 - (1 + r_1)^{-(N-n)}} + OC_{2i} \\ &= TPC(1 - x_1)p_2 \frac{r_1}{1 - (1 + r_1)^{-(N-n)}} + \psi OC_i \end{aligned}$$

#### IV. Case Study: Urban Railway PPP Project

This paper conducts a case study of an urban railway PPP project, referred to as the A-Line project, currently ongoing in the Seoul Metropolitan Area (SMA) in Korea, to derive the acceptable range of the contract conditions under the uncertainty of ridership forecasting.

The Ministry of Land and Transport (MOLT) put out a request for proposals (RFP) for the A-Line as a BTO-rs scheme in December of 2017 after assessing the project's profitability, benefit to the public, user affordability, and efficiency gains. Two bidders forming a consortium of builders, maintenance operators, and financial institutions submitted project proposals to the MOLT, and the MOLT started negotiations with the preferred bidder from May of 2018. However, the MOLT and a private concessionaire concluded an agreement that the project would proceed in October of 2018 as a standard BTO project due to the possible negative effects of BTO-rs contract conditions.

TABLE 1—PROPOSAL IN THE BTO-RS AND CONTRACTED CONDITIONS IN BTO

	BTO_rs (proposal)	BTO (contracted)
Length		43.6km
No. of stations		five stations
Construction Period		60 months
operation period		30 years
Total Project Cost (TPC)	KRW 2,953.4 billion	KRW 2,901.7 billion
Construction Cost	KRW 2,150.0 billion	KRW 2,143 billion
Construction Subsidy	KRW 455.3 billion	KRW 1,373.7 billion
Total Private Investment	KRW 2,837.7 billion	KRW 1,702.1 billion
Total Operation Cost (30 years)	KRW 3,723.0 billion	KRW 3,699.9 billion
Fare	KRW 2,419 + KRW 216 / 5km	KRW 2,592 + KRW 216 / 5km
Passengers in 2025	299,083 passengers / day	263,529 passengers / day
Passengers in 2030	298,981 passengers / day	262,279 passengers / day
IRR (BTO)	-	5.2%
Cost sharing portion by MOLT in private investment	40%	-
Shared portion by MOLT of excess operation profits	1.00%	-

Source: MOLT, "A-Line Concession Agreement," 2018.

The A-Line's length is 43.6km, and it is designed to pass through five stations. The total project cost was KRW 2,901.7 billion, of which KRW 1,373.7 billion was subsidized by the government and KRW 1,702.1 billion came from an investment by a private partner. The private concessionaire has the right to operate the A-Line for 30 years (See Table 1 for more details), with this contract expiring in 2054.

Table 1 presents the concessionaire's proposal for the BTO-rs scheme and the contracted conditions under the BTO scheme. Under the BTO-rs scheme, the concessionaire had requested 21.2% of the construction cost as a subsidy from the MOLT, while in the BTO contract, they concluded that 47.3% of the total project cost (TPC) would be paid by the government as a construction subsidy.

The contracted forecast ridership set by the contract is 73,159,276 passengers in 2024, the first year of service. After the opening year, the contracted forecast ridership ( $K_i$ ) increases steadily to 89,366,742 passengers in 2026, after which it decreases to 2045. The contracted forecast ridership remains fixed for ten years after 76,163,655 passengers in 2045.

Table 2 and Figure 2 show the contracted forecast ridership based on which the agreement between the concessionaire and the government was made.

The initial tariff on the first service date was contracted as the sum of the basic fare and travel distance fare. The basic fare was KRW 2,592 and the travel distance fare was KRW 216 for every 5 km. Subsequent fare adjustments are applied based on the cumulative monthly changes in the consumer price index (CPI) once a year, and the concessionaire reports this figure to MOLT after the fare change. Meanwhile, the basic fare was proposed as KRW 2,419 and the travel distance fare was KRW 216 for every 5 km under the BTO-rs scheme.

TABLE 2— YEARLY CONTRACTED FORECAST RIDERSHIP ( $K_t$ )

(Unit: passengers/year)

Year	Contracted Ridership (Passengers)	Year	Contracted Ridership (Passengers)	Year	Contracted Ridership (Passengers)
2024	73,159,276	2034	84,460,971	2044	76,864,766
2025	88,108,286	2035	83,653,540	2045	76,163,655
2026	89,366,742	2036	82,856,807	2046	76,163,655
2027	88,947,814	2037	82,060,075	2047	76,163,655
2028	88,528,551	2038	81,263,343	2048	76,163,655
2029	88,109,623	2039	80,466,611	2049	76,163,655
2030	87,690,361	2040	79,669,879	2050	76,163,655
2031	86,882,930	2041	78,968,768	2051	76,163,655
2032	86,075,499	2042	78,267,322	2052	76,163,655
2033	85,268,402	2043	77,566,211	2053	76,163,655

Source: MOLT, “A-Line Concession Agreement,” 2018.

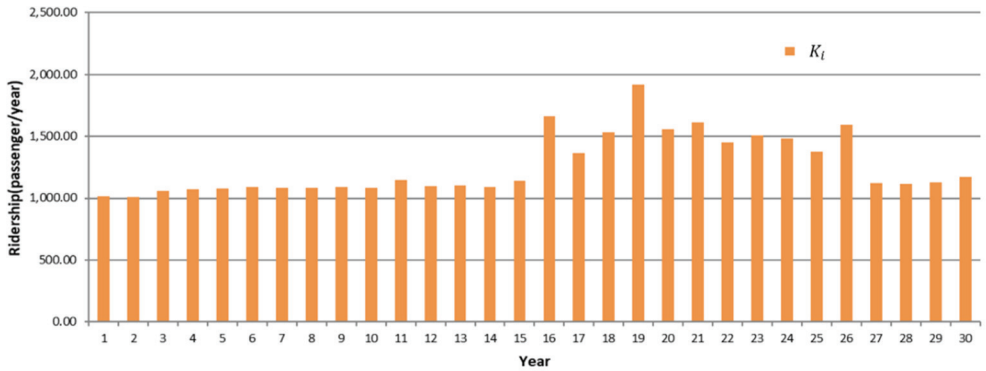


FIGURE 2. YEARLY CONTRACTED FORECAST RIDERSHIP ( $K_t$ )

V. Optimal Contract Conditions under the BTO-rs scheme

A. Objective Function

A multi-objective function is developed to establish the interest of the government and the private partner, i.e., to minimize the total government’s payments ( $GP$ ) for the entire operational period while maximizing the project’s NPV. The objective functions are optimized to derive the acceptable range of contract conditions under the BTO-rs scheme.

1. Objective Function for the Private Partner:  $F_1$

The first objective function is to maximize the NPV of the project and to search

for optimal contract conditions, such as  $(x_1, p_2, \psi, r_2, P)$  given the ridership for operational year  $i$ .

$$(4) \quad F_1(x_1, p_2, \psi, r_2, P | K_i, i = n+1, \dots, N)$$

Here,  $r_2$  is the expected rate of return for the government's shared cost of the private investment.

The private partner seeks to maximize the NPV of the project. The NPV function under the BTO-rs scheme is formulated as follows:

$$(5) \quad NPV = -\sum_{i=1}^n \frac{CC_{li}}{(1+r_2)^i} + \sum_{i=n+1}^N \frac{OR_{li} - OC_{li} + GP_i}{(1+r_2)^i}$$

Using equation (5), the first objective function under the BTO-rs scheme can be expressed as shown below. The NPV increases as  $P$ ,  $x_1$ , and  $p_2$  increase. However, the NPV decreases as  $\psi$  increases.

$$(6) \quad \begin{aligned} & F_1(x_1, p_2, \psi, r_2, P | K_i, i = n+1, \dots, N) \\ &= -\sum_{i=1}^n \frac{TPC(1-x_1)(1-p_2)}{(1+r_2)^i} + \sum_{i=n+1}^N \frac{(K_i P - OC_i)(1-\psi) + GP_i}{(1+r_2)^i} \end{aligned}$$

## 2. Objective Function for the Government: $F_2$

$$F_2(x_1, p_2, \psi, r_1, P | K_i, i = n+1, \dots, N)$$

The second objective function is to minimize total government's payments ( $GP$ ) for entire operational period. The objective of the government can be expressed in the form of various interests, such as maximization of social welfare or benefits and the provision of the service in time at a reasonable user fee level given applicable budget constraints. However, minimizing  $GP$  is set as an objective of the government, as the other interests are already considered or resolved during the project appraisal process.

Under the BTO-rs scheme,  $GP_i$  occurs when  $GC_i$  exceeds  $OR_{2i}$ .  $GP_i$  can be expressed by the following function, which includes the variable,  $p_2$ , the corresponding rate of return of the private partner's investment ( $r_2$ ),  $\psi$ ,  $x_1$ ,  $P$  and  $K_i$ .

$$(7) \quad GP_i(x_1, p_2, r_1, \psi, P, K_i) = \frac{TPC(1-x_1)p_2r_1}{1 - (1+r_1)^{-(N-n)}} - \psi(K_i P - OC_i)$$

Accordingly, the government's payments ( $GP$ ) for the entire operational period

can be established using the following equation:

$$(8) \quad F_2(x_1, p_2, \psi, r_1, P | K_i, i = n+1, \dots, N) = \left[ (N-n) \frac{TPC(1-x_1)p_2r_1}{1-(1+r_1)^{-(N-n)}} - \psi \sum_{i=n+1}^N (K_i P - OC_i) \right]^2$$

The government's payment is squared because it is assumed that the government minimizes unexpected increases in government payments to private investors arising from the BTO-rs scheme and does not seek to maximize financial revenue.

### B. Narrowing Down to Plausible Contract Conditions

The contract conditions as decision variables for optimizing the objective functions in this paper are  $p_2$ ,  $\psi$ , and  $x_1$ , given the contracted forecast ridership figure for operational year  $i$  ( $K_i$ ). We exclude other contract conditions  $P$ ,  $r_1$  and  $r_2$  for simplicity and for the convenience of the calculation. The value of  $r_1$ , indicating the expected rate of return for private investment, is set to 5.2%, which is the contracted IRR of the A-Line project. Additionally,  $r_2$  is set to 1.02% and is the level of the interest rate on Korea's government bonds. This implies an expected rate of return for the government's shared cost in the private investment. Regarding the range of  $P$ , it was increased from KRW 2,000 in KRW 100 intervals to a maximum of KRW 3,000, and sets of contract conditions ( $p_2$ ,  $\psi$ ,  $x_1$ ) are identified by optimizing the objective functions.

Before the robustness tests of the contract conditions are carried out, it is desirable to reduce the contract conditions to an ensemble of plausible futures. The study resolves this issue by restricting the range of the contract conditions and further by removing infeasible contract conditions. In particular, the set of feasible contract conditions is identified through a multi-objective optimization process using a genetic algorithm.

The initial values for  $p_2$ ,  $\psi$  and  $x_1$  are obtained from the proposed BTO-rs contract conditions for the A-Line project ( $x_1 = 16\%$ ,  $p_2 = 40\%$ ,  $\psi = 1\%$ ). In addition, the upper limit of  $x_1$  is set to 50%, which is the largest construction subsidy ratio for a railway PPP project in Korea.

Table 3 shows the initial value and lower- and upper-limit values for the determined contract condition variables ( $x_1$ ,  $p_2$ ,  $\psi$ ).

The NSGA-II algorithm (Hadka *et al.*, 2015) is used to identify feasible sets of contract condition variables that optimize the two objective functions. In the NSGA-II algorithm, if the initial solutions are given in the search space of the decision variables, a new set of candidate solutions is created through genetic modification (crossover and mutation), and individual candidate solutions are repeatedly evaluated during the search for optimal solutions. This paper generated 400 initial contract conditions ( $x_1$ ,  $p_2$ ,  $\psi$ ) given the levels of  $P$ ,  $r_1$  and  $r_2$ , contracted the

TABLE 3— INITIAL VALUES AND LOWER- AND UPPER-LIMIT VALUES  
OF THE CONTRACT CONDITION VARIABLES

Variables	Descriptions	Initial Value	Range
$x_1$	Ratio of the construction cost subsidy by the government to the total project construction cost	0.16(16%)	$0 \leq x_1 \leq 0.5$ (50%)
$p_2$	Ratio of investment cost sharing by the government to the total private investment	0.4(40%)	$0 \leq p_2 \leq 1.0$ (100%)
$\psi$	Ratio of excess profits or losses shared by the government to the operational profits or losses	0.01(1.0%)	$0 \leq \psi \leq 1.0$ (100%)

forecast  $K_i$ , and created offspring through crossover and mutation. The evolution process is repeatedly applied to a set of offspring more than 100 times.

The set of  $(x_1, p_2, \psi)$  that optimizes the objective functions is an approximate solution for the frontier that considers the offsetting effects of government payments and the project's NPV while being simultaneously deemed a set of selectable contract conditions.

### C. Feasible Contract Conditions

The fare ( $P$ ) is increased from KRW 2,000 in increments of KRW 100 to a maximum of KRW 3,000 and the sets of contract conditions  $(x_1, p_2, \psi)$  are investigated under the given levels of  $P$ ,  $r_1$  and  $r_2$  and the contracted forecast  $K_i$ .

Of the optimal set of  $(x_1, p_2, \psi)$ , sets of contract conditions that are deemed infeasible for both private investors and the government are excluded owing to the project's negative NPV, rendering the project itself unsustainable, and when the government's payment is very high. In particular, we exclude the set of contract conditions for which government payments exceeded KRW 30 million during the operational period and produced a negative NPV outcome.

Table 4 shows the 18 optimal sets of contract conditions  $(x_1, p_2, \psi)$ , the corresponding government payments, and the project's NPV under the given  $P$  after excluding infeasible contract conditions. The ratio of the construction subsidy to the total project cost ( $x_1$ ) is found to be close to the maximum value of 50%, and the ratio of excess profits or losses shared by the government to the operational profits or losses ( $\psi$ ) shows a rate of less than 20%.

Under the [No. 1] contract condition,  $x_1$  is 48.25%, close to the maximum of 50%, while  $p_2$  and  $\psi$  are insignificant at 1.44% and 0.51%, respectively. It was also found that the NPV is approximately 458.9 billion won and that no additional government payment had arisen. In particular, the analysis showed that it is possible to conclude a contract at fare 2,000 won, which is much lower than the current BTO project user fee of 2,700 won. Under the [No. 4] contract condition,  $x_1$  is calculated at 39.22%, which is far below the 50% maximum. However,  $p_2$  and  $\psi$  are also insignificant at 3.67% and 1.40%, respectively. The fare level is 2,100 won, which

TABLE 4— OPTIMAL CONTRACT CONDITIONS ( $x_1$ ,  $p_2$ ,  $\psi$ ),  $GP$ , AND NPV

Contract Conditions [No].	$P$ (Won)	$x_1$ (%)	$p_2$ (%)	$\psi$ (%)	$GP$ (KRW 10 Million)	NPV (KRW 10 Million)
1	2000	48.25	1.44	0.51	0.00	4589.17
2	2000	49.57	7.79	2.68	0.22	5376.70
3	2000	49.88	49.98	17.09	0.37	8489.59
4	2100	39.22	3.67	1.40	0.00	4118.16
5	2100	50.00	49.95	15.66	0.00	10069.90
6	2200	50.00	49.99	14.50	0.00	11634.20
7	2300	49.70	41.14	11.17	0.01	12509.76
8	2300	49.99	49.99	13.49	0.04	13197.20
9	2400	50.00	49.99	12.61	0.00	14762.96
10	2500	3.84	43.45	19.79	0.02	7177.64
11	2500	49.95	49.97	11.85	1.05	16317.23
12	2600	24.07	48.88	16.56	0.34	13134.24
13	2600	38.48	39.04	10.71	10.60	14881.25
14	2700	49.98	49.66	10.48	0.01	19436.51
15	2800	48.87	36.20	7.41	0.02	19831.08
16	2800	49.95	48.98	9.81	0.19	20949.70
17	2900	50.00	49.16	9.35	0.90	22540.01
18	3000	50.00	49.99	9.06	0.04	24166.19

Note: The table presents only contract conditions that are feasible for both private investors and the government.

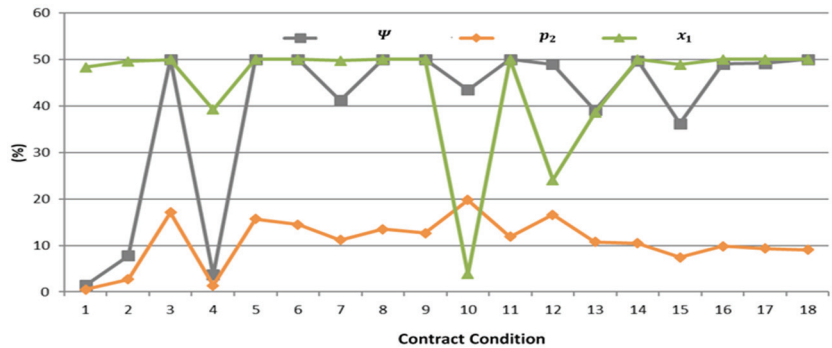
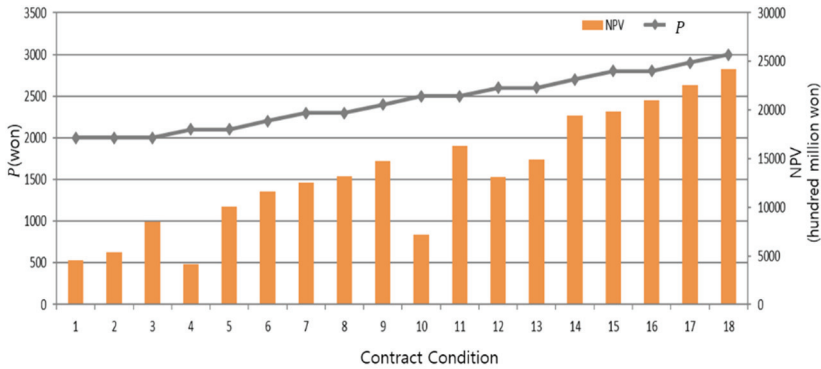


FIGURE 3.  $p_2$ ,  $\psi$  AND  $x_1$  ACCORDING TO THE SETS OF CONTRACT CONDITIONS

is lower than 2,700, and the NPV is 411.8 billion won. It was also found that no additional government payments had occurred.

Under the [No. 10] contract condition, where the user fee is 2,500 won,  $x_1$  is 3.84% which is lower than any other contract conditions. However,  $\psi$  shows the highest level, at 19.79%. As a result, the NPV is slightly lower at around KRW 717.8 billion. For the [No. 18] contract condition, where the NPV is largest,  $x_1$  and  $p_2$  are found to be highest.

FIGURE 4. *P AND NPV ACCORDING TO THE SETS OF CONTRACT CONDITIONS*

## VI. Robust Optimal Contract Conditions

We identified sets of contract conditions that optimize the two objective functions of maximizing the project's NPV and minimizing the government's payments ( $GP$ ). In the analysis thus far, however, the contracted forecast ridership for operational year  $i$  ( $K_i$ ) is used, consisting of the simple average and aggregate ridership forecasts and assuming that the ridership forecasts are accurate.

This section considers the uncertainty of ridership forecasts. By assuming that the probability distribution of ridership forecasting is not known and the uncertainty is not calculable or controllable, this paper suggests robust contract conditions that minimize the government payment and maximize the project's NPV, while also limiting the ranges of the variances in the government payment and the NPV in most situations.

### A. Uncertainty in Forecasted Ridership

To characterize uncertainty in ridership forecasts for the 30-year operation period, this paper assumes that the ridership forecast follows geometric Brownian motion (GBM) (see Kim *et al.*, 2012 and Kim, 2017), with GBM including all possible effects of the ridership forecasts caused by the uncertain variables. GBM, a model widely used in financial engineering, is used to predict the movements of variables with deep uncertainty (see Martin and Rennie, 1996). In the GBM model, once variables move in one direction, the probability of moving in the same direction increases. This phenomenon is observed in actual travel demand. It should be noted that any specification method such as random sampling or bootstrapping can be applied for uncertainty specification of the ridership forecast. According to GBM, the forecasted ridership of the A-Line during year  $t$  is dependent on the increasing rate ( $\alpha$ ) and corresponding volatility ( $\sigma$ ) (Eq. [9])

$$(9) \quad dK_t = \alpha K_t dt + \sigma K_t dW_t, \text{ or } K_t = K_0 \exp \left[ \left( \alpha - \frac{\sigma^2}{2} \right) t + \sigma W_t \right]$$



Here,  $K_t$  is the ridership of the A-Line in year  $t$  and  $K_0$  is the ridership in the first year of service.  $W_t$  is the standard Wiener process that follows a normal distribution, where the average is 0 and the standard deviation is 1.  $\alpha$  is the increasing rate of ridership and  $\sigma$  is the corresponding volatility.

The ridership for the opening year ( $K_0$ ) in equation (9) is generated based on the probability distribution of the ridership forecasting error ( $E$ ) in currently operating Korean PPP projects. After defining the ridership forecasting error ( $E$ ) as the forecasted ridership ( $K_f$ ) relative to the actual out-turn ridership ( $K_\alpha$ ),  $K_0$  is then generated using a random number ( $e$ ) of the probability distribution of  $E$  and  $K_f$ .

Note that  $K_f$  is the contracted forecast ridership for the commercial operational year of the A-Line, which in this case is 3,159,276 passengers.

$$(10) \quad E = \frac{K_\alpha}{K_f} \times 100 \text{ (\%)}$$

The parameters of the probability distribution of the ridership forecasting error ( $E$ ) are estimated using the actual out-turn ridership in the currently operating PPP projects, i.e., the Incheon Airport Railroad, New Bundang Line, SMA Line 9, Busan-Gimhae Light Railway and the Uijeongbu Light Railway. Meanwhile, to generate  $K_t$ , the increasing rate of ridership ( $\alpha$ ) and its volatility ( $\sigma$ ) are applied from the actual observations of the above PPP projects. They are currently running throughout the Seoul Metropolitan Area, where the A-Line is located. In particular, the study considers the ramp-up effect of ridership during the operation year by applying different increasing rates of  $\alpha$  and  $\sigma$ . Ramp-up refers to the phenomenon of the actual ridership changing. The ridership fluctuates during the early service period, but it is expected to stabilize over time. This study found that the number of passengers was highly volatile during the first six years after the opening of the service, after which it stabilized (SMRTC, 2008). Accordingly, this paper sets  $\alpha^1$  and  $\sigma^1$  to 0.147 and 0.097, respectively, from the opening year to the sixth year of the service, and sets  $\alpha^2$  and  $\sigma^2$  from the seventh year to the thirtieth year of service to 0.0147 and 0.0097, respectively, values which are assumed, correspondingly, to be 10% of  $\alpha^1$  and  $\sigma^1$ . Meanwhile, to consider the wide range of possible values of  $K_t$ , a combination of  $\alpha$  and  $\sigma$  is used. The minimum and maximum values of  $\alpha$  and  $\sigma$  are set to 50% and 150% of the reference values in each case, with  $K_t$  then generated using a combination of values of  $\alpha$  and  $\sigma$  within these limits. Accordingly, from the opening year to the fifth year of service, we assume that the probability distributions of  $\alpha^1$  and  $\sigma^1$  follow uniform distributions with a lower limit of 50% and an upper limit of 150% around the

baseline values (  $\alpha_b^1 = 0.1471$ ,  $\sigma_b^1 = 0.0966$  ). Meanwhile,  $\alpha_b^2$  and  $\sigma_b^2$  are assumed to be 77% (1/1.3) of  $\alpha_b^1$  and 71.4% (1/1.4) of  $\sigma_b^1$ , respectively (i.e.,  $\alpha_b^2 = 0.1132$ ,  $\sigma_b^2 = 0.069$  ), from the sixth year to the thirtieth year of service.

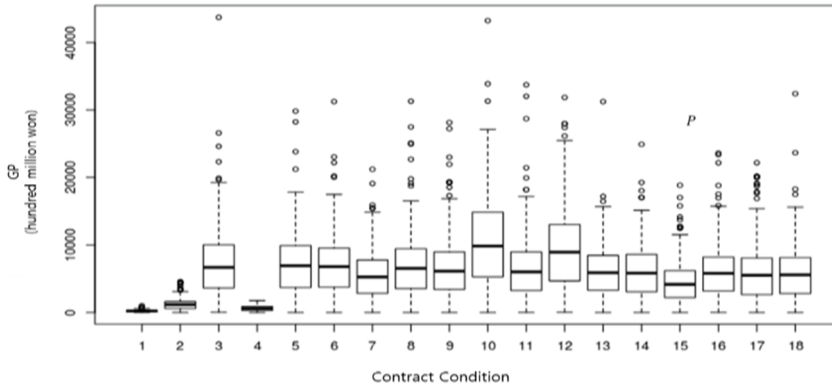
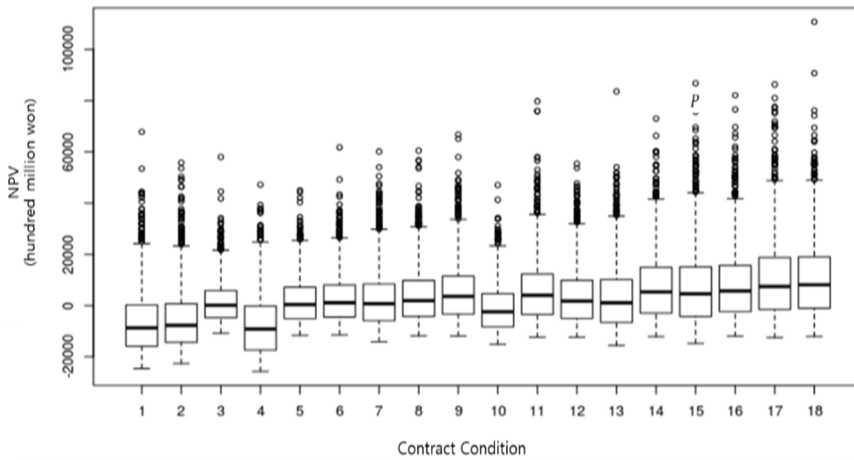
### B. Variations in $GP$ and $NPV$ caused by the uncertainty in ridership forecasts

This section identifies the variations of  $GP$  and  $NPV$  given the 18 sets of contract conditions ( $P$ ,  $x_1$ ,  $p_2$ ,  $\psi$ ) according to the uncertainty of the forecasted ridership. To do this,  $K_t$  is generated five hundred times using random numbers of the uniform probability distributions of  $\alpha$  and  $\sigma$  and the exponential distribution of the ridership for the opening year ( $K_0$ ).

Table 5 shows the mean and standard deviation of  $GP$  and  $NPV$  of the project in the 18 sets of contract conditions caused by the uncertainty of ridership forecasts. For instance, in the [No. 1] contract condition, mean and the corresponding standard deviation of  $GP$  are 21.12 and 12.04 billion, respectively. The corresponding  $NPV$ 's mean and standard deviation are KRW 661.64 and KRW 1217.00 billion, respectively. Among the 18 sets of optimal contract conditions, the standard deviation of  $GP$  is small in the order of [No. 1], KRW 12.04 billion; [No. 4], KRW 34.47 billion; and [No. 2], KRW 64.98. The standard deviation of  $NPV$  is small in the order of [No. 3], KRW 800.23 billion; [No. 5], KRW 871.14 billion; and [No. 10], KRW 924.09 billion.

TABLE 5— MEAN AND STANDARD DEVIATION OF  $GP$  AND  $NPV$  UNDER THE GENERATED  $K_t$

Contract Conditions [No.]	$P$ (KRW)	$x_1$ (%)	$p_2$ (%)	$\psi$ (%)	$GP$ (KRW Billion)		$NPV$ (KRW Billion)	
					Mean	Std. Dev	Mean	Std. Dev
1	2000	48.25	1.44	0.51	21.12	12.04	661.64	1217.00
2	2000	49.57	7.79	2.68	113.36	64.98	554.44	1188.44
3	2000	49.88	49.98	17.09	692.36	404.90	123.32	800.23
4	2100	39.22	3.67	1.40	59.86	34.47	765.29	1205.88
5	2100	50.00	49.95	15.66	679.63	386.10	178.62	871.14
6	2200	50.00	49.99	14.50	667.77	366.88	272.22	955.98
7	2300	49.70	41.14	11.17	531.32	299.26	241.68	1093.60
8	2300	49.99	49.99	13.49	649.61	367.22	387.91	1058.60
9	2400	50.00	49.99	12.61	621.69	359.12	522.34	1138.62
10	2500	3.84	43.45	19.79	1000.88	573.83	101.90	924.09
11	2500	49.95	49.97	11.85	613.38	359.56	567.34	1192.24
12	2600	24.07	48.88	16.56	888.67	509.00	355.45	1085.21
13	2600	38.48	39.04	10.71	584.20	323.89	319.18	1253.32
14	2700	49.98	49.66	10.48	578.81	333.67	731.48	1289.38
15	2800	48.87	36.20	7.41	422.88	248.03	698.98	1491.35
16	2800	49.95	48.98	9.81	574.87	320.08	811.72	1376.81
17	2900	50.00	49.16	9.35	548.37	329.51	997.58	1483.32
18	3000	50.00	49.99	9.06	551.51	322.73	1035.56	1485.88

FIGURE 5. DISPERSION OF  $GP$ FIGURE 6. DISPERSION OF  $NPV$ 

The [No. 10] contract condition shows the highest expected  $GP$ , while the highest  $NPV$  occurs in the [No. 18] contract conditions. These results show that there is a risk of excessive government payments to the private partner as well as non-profitability of the project due to the uncertainty of ridership forecasting.

### C. Robust Contract Conditions under Ridership Forecasting Uncertainty

This section presents robust contract conditions among the 18 sets of contract conditions that minimize any unforeseen increase in government payments and the deterioration of the viability of the project as possibly caused by ridership forecasting uncertainty.

The robustness evaluations of the 18 sets of contract conditions are conducted considering the following regret-based measures presented by Herman *et al.* (2015). Herman *et al.* (2015) defined the robustness evaluation indicator  $R_i$ , for objective function  $i$  as the rate of change of the objective function  $i$  relative to the predetermined baseline value of the objective function.

$$(11) \quad R_i(c) = q_{s \in S} \left( \left| \frac{F_i(c, s) - F_i(c, \bar{s})}{F_i(c, \bar{s})} \right|, 0.9 \right), \quad i = 1, 2, \dots, N$$

Here,  $q(\cdot, 0.9)$  refers to the ninetieth percentile and  $F_i(c, s)$  refers to the value of the objective function  $i$  consisting  $c$  and  $s$ . In addition,  $c$  refers a set of contract conditions  $(x_1, p_2, \psi)$  and  $s$  is the element of  $S$ , which is a set of parameters related to the uncertainty of the ridership forecast,  $K_0$ ,  $\alpha$  and  $\sigma$ . Moreover,  $\bar{s}$  represents the baseline values of  $K_0$ ,  $\alpha$  and  $\sigma$ , and  $N$  refers to the number of objective functions, a value which is two here.

The denominator, which is the value of the objective function  $F_i(c, \bar{s})$ , can be zero in equation (11). Accordingly, this paper adopted the robustness evaluation indicator  $R_i$  as the robustness value. It is defined as shown below.

$$(12) \quad R_i(c) = q_{s \in S} (\max(F_i(c, s) - F_i(c, \bar{s}), 0), 0.9)$$

Meanwhile, when the values of the respective objective functions have identical units and are comparable, the upper limit of  $R_i$  can be used as the regret-based measure, and the ninetieth percentile of the set of contract conditions is assumed contains robust contract conditions.

$$(13) \quad R(c) = \max_i \{R_i(c), i = 1, \dots, N\}$$

Table 6 shows the 18 sets of optimal contract conditions  $(x_1, p_2, \psi)$  and the corresponding values of  $R_1$  and  $R_2$ . If  $R_1$ , indicating the robustness measure of  $F_1$ , is large, it can be said that the  $NPV$  of the project fluctuates considerably according to the uncertainty of the ridership forecasts. If  $R_2$  is small, it can be said that  $GP$  changes only slightly according to the uncertainty of the ridership forecasts, and the contract condition is a robust condition which enables the government to minimize the vulnerability and negative results of  $GP$ . Accordingly,  $R_2$  shows the largest value in the [No. 10] contract condition, whereas for  $R_1$ , [No. 18] has the largest value.  $R_2$  is small in the order of contract conditions [Nos. 1, 4, 2], where  $p_2$  and  $\psi$  are insignificant. This arises because with smaller values of  $GP$ ,  $p_2$  and  $\psi$ , less change occurs in  $GP$ . On the other hand, the  $R_1$  values are small in the order of the [No. 2], [No. 1], [No. 10] and [No. 4] conditions.

Considering  $R_1$  and  $R_2$  at the same time, the sets of contract conditions [No. 1], [No. 2] and [No. 4] are suggested to be the most desirable robust contract conditions for the A-Line project, as they minimize unforeseen increases in government payments and the deterioration of the viability of the project possibly caused by uncertainty in the ridership forecasts.

The robust contract conditions suggest  $x_1$  as 48.25%, 49.57% and 39.22%, respective to the conditions above. They also correspondingly suggest  $p_2$  as 1.44%,

TABLE 6—  $R_1$  AND  $R_2$  IN THE SETS OF CONTRACT CONDITIONS

Contract Conditions [No].	$P$ (KRW)	$x_1$ (%)	$p_2$ (%)	$\psi$ (%)	$R_1$	$R_2$
1	2000	48.25	1.44	0.51	17923.38	366.19
2	2000	49.57	7.79	2.68	15904.79	1958.61
3	2000	49.88	49.98	17.09	20264.04	12181.48
4	2100	39.22	3.67	1.40	19241.65	1064.81
5	2100	50.00	49.95	15.66	23954.98	11906.76
6	2200	50.00	49.99	14.50	27350.62	11365.37
7	2300	49.70	41.14	11.17	29434.33	9184.91
8	2300	49.99	49.99	13.49	31433.40	11134.05
9	2400	50.00	49.99	12.61	35334.64	10808.10
10	2500	3.84	43.45	19.79	19153.82	17702.72
11	2500	49.95	49.97	11.85	37303.27	10566.78
12	2600	24.07	48.88	16.56	30703.16	15407.15
13	2600	38.48	39.04	10.71	35557.77	10062.51
14	2700	49.98	49.66	10.48	44154.89	10136.89
15	2800	48.87	36.20	7.41	46077.94	7465.47
16	2800	49.95	48.98	9.81	47970.95	9844.12
17	2900	50.00	49.16	9.35	52050.39	9677.41
18	3000	50.00	49.99	9.06	53683.86	9663.22

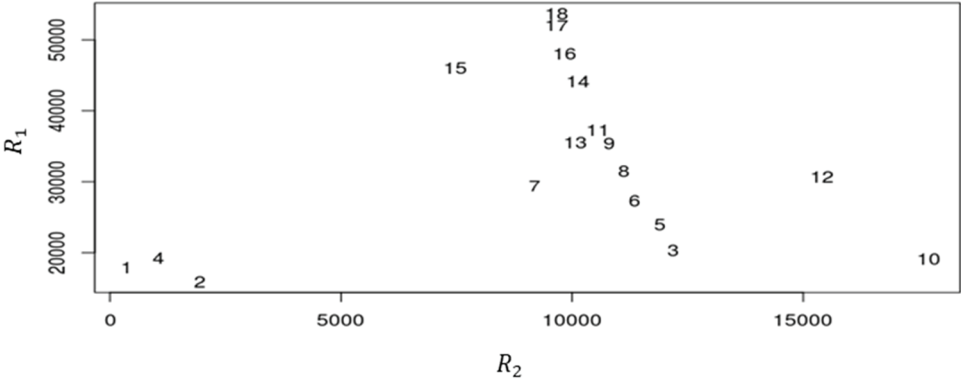


FIGURE 7. SCATTER DIAGRAM OF  $R_1$  AND  $R_2$

7.79% and 3.67% and  $\psi$  as 0.51%, 2.68% and 1.40% in [No. 1], [No. 2] and [No. 4].

D. Comparison Total Government Payment and User Fee  
between the BTO-rs and BTO Schemes

MOLT put out a request for proposals (RFP) for the A-Line project as a BTO-rs scheme; however, MOLT and a private concessionaire concluded an agreement that the project will be processed as a standard BTO project due to the possible negative effects caused by the BTO-rs contract conditions. In this section, the total government payment and fare level amounts are compared between the suggested

18 contract conditions and a current BTO contract condition.<sup>5</sup> Here, the total government payment is the amount including the construction cost subsidy by the government for the BTO contract and *GP* as well as the construction subsidy in the case of BTO-rs scheme. In the current BTO contract, 47.3% of the total project cost is paid by the government as a construction subsidy, and the user fee is KRW 2,707.

Note that contract conditions [No. 1], [No. 2] and [No. 4] were robust contract conditions under the BTO-rs scheme. Table 7 shows that the total expected government payments in contract conditions [No. 4] and [No. 10] are smaller than those of the current BTO contract among the 18 contract conditions. The fare levels are also KRW 2,100 and KRW 2,500, respectively, which are lower than the KRW 2,707 of the current BTO contract. However, the [No. 10] contract condition is not robust and is exposed to the risk of incurring additional government payments due to the uncertainty of ridership forecasts. In addition, for the [No. 2] contract condition, suggested as a robust contract condition under the BTO-rs scheme, the total expected government payment for the project is KRW 1,551.76 billion, which exceeds the value of KRW 1,373.7 billion under the current BTO contract. Accordingly, the [No. 4] contract condition is more suitable under the BTO-rs scheme from the perspective of the government and users. The total government payment is estimated to be KRW 1197.95 billion under the [No. 4] contract condition.

TABLE 7— COMPARISON OF TOTAL GOVERNMENT PAYMENTS AND USER FEES  
BETWEEN THE BTO-RS AND BTO SCHEMES

Contract Conditions [No.].	Total Government Payment (KRW billion)		User Fee (KRW)	
	BTO-rs	BTO	BTO-rs	BTO
1	1,421.12	1,373.70	2,000	2,707
2	1,551.76	1,373.70	2,000	2,707
3	2,139.66	1,373.70	2,000	2,707
4	1,197.95	1,373.70	2,100	2,707
5	2,130.47	1,373.70	2,100	2,707
6	2,118.54	1,373.70	2,200	2,707
7	1,973.35	1,373.70	2,300	2,707
8	2,100.23	1,373.70	2,300	2,707
9	2,072.45	1,373.70	2,400	2,707
10	1,112.18	1,373.70	2,500	2,707
11	2,062.70	1,373.70	2,500	2,707
12	1,587.14	1,373.70	2,600	2,707
13	1,700.89	1,373.70	2,600	2,707
14	2,029.22	1,373.70	2,700	2,707
15	1841.08	1,373.70	2,800	2,707
16	2024.3	1,373.70	2,800	2,707
17	1999.22	1,373.70	2,900	2,707
18	2002.35	1,373.70	3,000	2,707

<sup>5</sup>It is impossible to compare NPVs of the project because there is no data for the current BTO contract.

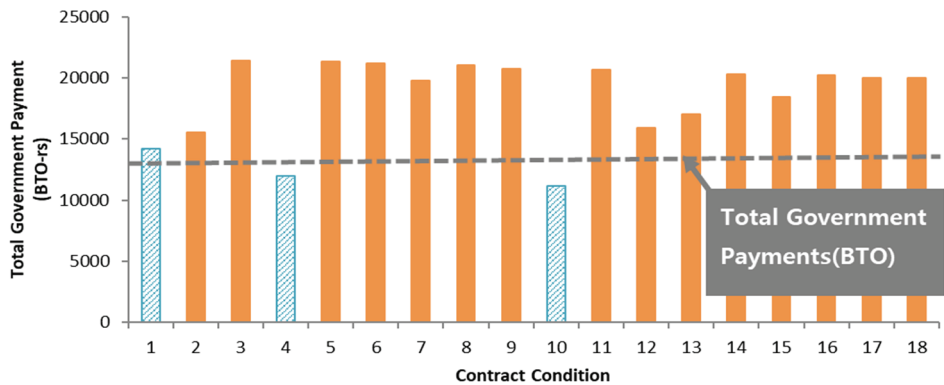


FIGURE 8. COMPARISON OF TOTAL GOVERNMENT PAYMENTS

VII. Summary and Conclusion

PPP projects in Korea face criticism due to unexpected hikes in the government’s payments to private partners and high user fees. Accordingly, the Korean government has been striving to reduce its financial burden and lower user fees, and it introduced the BTO-rs scheme to lower the high user fees by reducing the project risk borne by private partners.

This paper suggested robust BTO-rs contract conditions that minimize negative effects on governments and private partners considering the uncertainty in ridership forecasts. The sets of contract conditions for which government payments resulted in more than KRW 30 million for the operational period and negative NPV outcomes were excluded, and robust contract conditions that could reduce government payments and user fees while maintaining clear profitability of the project were selected. When we compared the robust contract conditions of the current BTO contract and determined the total expected government payment in the [No. 4] condition, we suggested  $x_1$ ,  $p_2$  and  $\psi$  rates of 39.22%, 3.67% and 1.40%, respectively, which were lower than those of the current BTO contract. In addition, the fare level was KRW 2,100, which is lower than the KRW 2,707 of the current BTO contract.

Several areas can be suggested for further study. In this paper, the GBM model is adopted to determine the probability distribution of the forecasted ridership. It should be noted that the generated ridership depends on the probability distribution of the GBM, which could, in turn, can change the robust contract conditions. Further research on the probability distribution of the ridership are needed. Finally, further research is needed with regard to how much weight should be assigned toward each object function to derive more practical and reliable contract conditions.

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