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Determinants of Regional Economic Performance in North Korea: Evidence from Satellite Nighttime Lights

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Abstract

This dissertation investigates the status and the determinants of regional economic performance in North Korea, overcoming data limitations of regional research on the North Korean economy using nighttime light data and geospatial data.

The first chapter estimates regional level GDP per capita, assessing the regional economic inequality of North Korea at the county level using nighttime light as a proxy for economic level. The research calculates base gross regional domestic product (GRDP) per capita based on urbanization rates and Bank of Korea's GDP estimates and derives nighttime light-based GRDP per capita based on the relationship between base GRDP per capita and nighttime light. It also assesses the inequality of North Korean regions at the county level, revealing severe county-level inequality within the province, representing 87% of the total inequality, whereas most previous studies have focused on between-province inequality.

In the second chapter, the determinants of regional economic performance in the Kim Jong-un era are analyzed using nighttime light as a proxy for economic performance, revealing that market size and involvement in trade, measured as proximity to trade hubs, contribute to higher nighttime light, while industries do not appear to have a significant effect. Sanctions are shown to significantly reduce nighttime light overall, but the magnitude of the impact is highly divergent across regions. The damage of sanctions is greater in regions with large markets or near trade hubs. In contrast, regions near major wholesale markets appear to better cope with sanctions, although the aggregate effect of sanctions on the region is negative.

In the final chapter, the channel of trade effect on regional economies is investigated for the period of recovery from the "Arduous March," 2001–2016. Three hypotheses of export-led growth, import-led growth, and marketization channel are examined. Historical data from the Japanese colonial era are used as instrumental variables to manage the endogeneity problem of the market. The results indicate that resource export and growth of market in response to trade are the main channels through which sanctions affect regional economies. Conversely, input import does not affect regional economies through any industry. The findings imply that North Korea's economic recovery from the Arduous March was mainly the result of resource export and market expansion.

Keywords: North Korean Regional Economies, Marketization, North Korean Trade, Nighttime Light, Geospatial Data.
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Introduction

North Korea is one of the most restrictive countries in the world in terms of data accessibility. Even the construction of basic statistics of GDP relies on estimates from the outside world, such as the UN and the Bank of Korea, which also depend on insufficient information. This data deficiency is more prominent for investigating issues at a regional level, for which the only possible regional level data available are two censuses by the UN Population Fund and a handful of survey statistics mainly concerning health status. Hence, most of the regional level studies have been qualitative research based on the interview with North Korean defectors, or descriptive analysis based on few nationwide surveys on health and welfare.

According to Fujita et al. (1999), economic forces, including increasing returns, transportation costs, and factor mobility generate spatial unevenness. These forces lead to the agglomeration of economic activities in certain regions, creating regional disparities. However, many diverse features of regional heterogeneity emphasized by economic geography literature have remained undiscovered due to the aforementioned unavailability of data. The effects of market and trade, factors that are considered to be the main drivers of North Korean economic growth in recent years, have rarely been analyzed at the regional level, although they take place in specific regional locations.

Satellite-observed nighttime light data has recently opened a new path for economic research of countries with poor data quality. The data are inherently objective in quality, comprehensive in coverage, and detailed in the spatial units provided. Henderson et al. (2012) and Chen and Nordhaus (2011) used nighttime light as a major instrument to improve the measurement of GDP statistics, finding the assessment of nighttime light to contribute to improvement in the quality of GDP statistics, particularly in data-poor countries. Much research finds a positive association between nighttime light and various socioeconomic variables (Ma, Zhou, Pei, et al., 2014; Ma, Zhou, Wang, et al., 2014; Bruederle & Hodler, 2018), or use it as a proxy for economic level (Shenoy, 2018; Storeygard, 2016; Hodler & Raschky, 2014).

This thesis uses satellite nighttime light data to estimate the economic performance of North Korean regions and to investigate its determinants. Market and trade, which are the two main drivers of economic growth in North Korea since the 1990s, are considered major factors. In recent years, sanctions are another factor that have affected North Korea. As sanctions prohibit major sources of foreign currency acquisition, it is expected to hurt the economy. To examine the effects of the aforementioned factors, various sets of spatial information from the previous literature, North Korean media, and geographical information from maps are used in combination with nighttime light data to analyze the regional economies of North Korea.

The first chapter estimates regional level GDP per capita and assesses regional inequality in North Korea at the county level. Regional inequality in North Korea is found to be sizable, the majority of which stems from within-province, although only between-province inequality, mostly between Pyongyang and other provinces, has been emphasized in the previous literature(이석, 2015; 김석진 & 홍제환, 2019).

In the second chapter, the determinants of regional economic performance in the Kim Jong-un era are analyzed using nighttime light as a proxy for economic performance. The results reveal that market size and involvement in trade, measured as the proximity to trade hubs, contribute to higher nighttime light. However, sanctions significantly reduce the average nighttime light and more severely damage the regions with large markets or near trade hubs. In contrast, regions near major wholesale markets appear to better cope with sanctions, although the aggregate effect of sanctions on the region is negative. This indicates that the market and trade are major contributing factors of the North Korean economy in the Kim Jong-un era and sanctions considerably damage the core of the North Korean economy.

In the final chapter, the channel of trade effect on regional economies is investigated for the period 2001–2016. Three hypotheses of export-led growth, import-led growth, and marketization channel, which is a positive externality of trade, are examined. To rule out endogeneity, historical data from the Japanese colonial era and official documents from North Korea in the 1980s are used. The results indicate that resource export and growth of the market in response to trade are the main channels of benefit from trade. In contrast, inputs import does not affect regional economies through any industry. The findings imply that the recovery of the North Korean economy from the Arduous March mainly resulted from resource export and expansion of the market.

This thesis contributes to the previous research in the following four respects. First, it helps to expand the understanding of the status of North Korean regional economies. Previous research on regional economies in North Korea has mostly been qualitative research on certain cities(정은이, 2020; 홍민, 2016) or at the province level(이석, 2015; 김석진 & 홍제환, 2019). This research builds on the findings of the previous research, providing a detailed and comprehensive analysis and new insights regarding North Korean regional economies at the county level.

Second, it uses a variety of novel datasets, including satellite nighttime light data, historical data, and map-based geographical data that have not been used in previous research. The use of new data allows a quantitative approach to economic questions on the North Korean economy from a regional panel framework that has rarely been used.

Third, this study empirically estimates the determinants of the

North Korean regional economies, with implications regarding the nation's economic growth since the 2000s, finding sizable effects of market and trade on the regional economies. Moreover, it finds that trade and market enhance one another, boosting regional economies. In contrast, the effect of the formal sector appears insignificant. These results imply that the free economic activities of lower-level economic agents, rather than a national top-down strategy and economic system, are critical factors for North Korea's economic growth.

Lastly, this research estimates the impact of sanctions and the attending transmission channels. The results indicate that the impact of sanctions is highly divergent across regions. Regions that took the lead economically prior to sanctions are affected more severely by them, whereas regions near domestic distribution hubs appear to better cope with sanctions. The result demonstrates the effectiveness of sanctions and reveals how the North Korean economy has responded.

Chapter 1. Estimation of North Korean Regional GDP in 2012-2019 Using Nighttime Light Data

1. Introduction

Although many studies on regional economies have been conducted in economics, research on the North Korean regional economies is at a primitive stage, mainly due to data constraints. North Korea is one of the most restrictive countries in terms of data accessibility. Even statistics on the national account system that is basic for most countries are not provided by North Korea. The only existing data are estimates from the UN statistics division and the Bank of Korea. The situation is even worse for data at the regional level. Only a few nationwide surveys have been conducted regarding welfare status, such as health and living conditions, with the help of international organizations. Although such surveys provide valuable information, the statistics are provided only at the province level, and the serial consistency and accuracy of the survey results are poor.

Many existing North Korean regional studies have analyzed the available surveys in a descriptive manner (임을출 et al., 2015). Others focused only on some important cities to study the aspects and effects of marketization (홍민 et al., 2019), the use of formal sector firms (정은이 et al., 2020) and the development of cities (박세훈 et al., 2016). Such studies are mainly based on interviews with North Korean defectors. Other researchers have used novel datasets, including satellite imagery, official documents, and books issued by the North Korean government. 홍민 et al. (2016) constructed a North Korean official market dataset based on satellite imagery and interviews with the North Korean defectors. It contains information on the markets' names, sizes, the number of vendors, market tax, and other considerations. 류학수 (2019) analyzed the industrial distribution of North Korean formal firms based on 『조선지리전서』, which was published in 1984.

Recently, a new kind of dataset is being widely used in the study of the North Korean economy in addition to research on countries with limited statistical ability and existing data; that is, satellite imagery of nighttime light data. The data is objective in quality and thorough in coverage since it is observed via satellite. The data is also provided in 15–30 arc second spatial resolution, which makes sub–national research possible. As a result, many studies have examined the relationship between nighttime light and socioeconomic variables such as urbanization rate, GDP, built area density, electricity consumption, and other economic concerns (Ma, Zhou, Pei, et al., 2014; Ma, Zhou, Wang, et al., 2014). In particular, Bruederle and Hodler (2018) confirmed that nighttime light data is a valid proxy for welfare status, such as school attendance rate, toddler mortality rate, and household wealth, even in countries with low electricity accessibility.[1]

Moreover, nighttime light data has also been used as a proxy for GDP per capita in various studies (Shenoy, 2018; Hodler and Raschky 2014; Pinkovskiy and Sala–i–Martin, 2016), as a major instrument to improve the quality of GDP statistics. Henderson, Storeygard, and Weil (2012), pioneering researchers in the use of nighttime light data in economics, estimated GDP based on nighttime light, presenting the optimal weight between national GDP statistics and nighttime light derived GDP. Nordhaus and Chen (2015) took a similar approach, investigating the validity of the estimation result by bootstrap. They concluded that nighttime light data provides abundant cross–sectional information and can contribute to improving the GDP statistics of countries with low statistical abilities.

[1] Bruederle and Hodler (2018) used geo–referenced demographic and health survey data and matched it with nighttime light of 28 African countries at a cluster level, demonstrating that nighttime light data explains the various welfare measures noted.

Nighttime light data is also used in North Korean research. 김규철 (2017) and 김정아 & 천상현 (2020) analyzed the trend of the nighttime light observed by DMSP-OLS[2] deriving implications on North Korean economy. Lee (2018) used nighttime light to analyze the impact of sanctions on the North Korean economy, finding diminishing light in capital cities, North Korea–China border cities, and industrial cities as the intensity of sanctions increased. Cuaresma et al. (2020) estimated province-level GRDP per capita in North Korea by applying the relationship between GRDP per capita and the nighttime light data of Chinese provinces, using it to identify the most similar economy (country and period) with North Korea for estimating the sub-national poverty rate. Although nighttime light data is used in a few studies of the North Korean economy, most focus on major cities or perform province-level or national-level studies. Thus, the economic status and inequality of North Korea at the county level have not been thoroughly or comprehensively studied despite the high spatial resolution of the data.

This research aims to estimate county-level GRDP per capita and assess the inequalities in North Korean regions using nighttime light data. GRDP per capita is estimated in two steps. First, the base GRDP per capita is calculated proportional to county-level urbanization rates and GDP estimate from the Bank of Korea. Second, the base GRDP per capita is regressed on the sum of light (SOL), and the nighttime light-based GRDP per capita is derived by fitting the data to the estimated equations. Then, the regional economic status and regional disparity are assessed and discussed. The research reveals substantial county-level inequality, implying that provincial-level analysis alone is insufficient for studying North Korean inequality. The research also reveals that sanctions

[2] The Operational Linescan System (OLS) hosted by the Defense Meteorological Satellite Program (DMSP) of the US National Oceanic and Atmospheric Administration.

alter the distribution of the most vulnerable regions from the inland, southern regions to North Korea–China border regions.

The remainder of this chapter is organized into four sections. Section 2 introduces the details of the nighttime light data, concerns regarding its use for research on North Korea, and the relationship between nighttime light and North Korean welfare statistics. In section 3, the methods to estimate GRDP per capita and inequality are presented and introduces the other sets of data used in this study. Section 4 presents and discusses the results, and section 5 concludes.

2. Nighttime Light Data

2.1. Introduction

There are 2 sets of nighttime light data that are observed by different satellites: NPP−VIIRS and DMSP−OLS. NPP−VIIRS nighttime lights data is operated by NASA and the National Oceanic and Atmospheric Administration(NOAA) and can be downloaded from the NOAA website (Elvidge et al., 2021). The data is given in monthly and annual terms and is available since 2012. The spatial resolution of the data is 15 arc second, which is about 500 meters in North Korean territory, and the overpass time is 1:30 AM. The other nighttime light data is the one observed by the DMSP−OLS satellite. The satellite is operated by the department of defense of the United States and annual data for 1992−2013 is provided. The spatial resolution is 30 arc second which is about 1km, and the overpass time is 20:30 – 21:30.

There are some weaknesses of DMSP−OLS observed nighttime light data. Most of all, there have been changes in the satellites and even within the observation periods of the same satellite, there's a degradation problem as the satellite ages. Thus the direct comparison of the nighttime lights level across the period is inappropriate. The performance and sensitivity vary not only across the satellites but also across periods within the same satellite. Also, the nighttime light data is provided within the 0-63 digital number range so that there is censoring from below and above. For many countries, censoring from above known as saturation is a problem. However, censoring from below is a serious problem for North Korea since the level of nighttime lights brightness is low. Also, spread lights are observed by the satellite which causes the lights from China and South Korea to be captured in the North Korean territory.

The nighttime light data observed by the NPP-VIIRS satellite is improved in several respects over DMSP-OLS data. It is observed by the same satellite and the sensitivity of the satellite is enhanced so that it can detect the light as dim as a single street lamp (Bennett and Smith, 2017). Also, there's no saturation and the spread of lights is alleviated. Figure 1-1 is the nighttime lights data by NPP-VIIRS and DMSP-OLS in the same 2012. The alleviated spread of lights can be seen from the regions near Pyongyang and inter-Korean borders. The lights from the metropolitan of South Korea and Pyongyang are spread to nearby areas in the DMSP-OLS dataset, whereas the phenomenon is improved in the NPP-VIIRS dataset.

Figure 1-1. NPP-VIIRS and DMSP-OLS Nighttime Light in 2012

Note: Left panel is the NPP-VIIRS data and right panel is the DMSP-OLS data

Figure 1-2 shows the number of counties that lights are observed in 1992-2020. For 2012 and 2013 when the two types of datasets jointly observe the lights of, NPP-VIIRS detects lights from about twice as many counties as the DMSP-OLS satellite does. Since the performance of the NPP-VIIRS satellite excels DMSP-OLS satellite, this research utilizes VIIRS-NPP observed nighttime lights data.

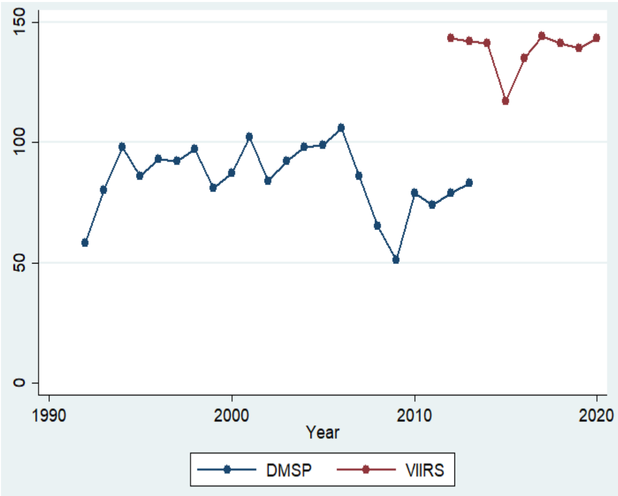

Figure 1-2. The Number of Lit Counties

2.2. Features of Energy Use in North Korea

Energy consumption in North Korea has some unique features that must be considered in any economic research of North Korea that uses nighttime light data. First, the nighttime light may represent electricity supply, not the economically meaningful electricity demand. North Korea has long suffered from a shortage of electricity supply, although the energy industry has been regarded as one of the top priority industries by the North Korean government. In such circumstances, variations in luminosity may represent variations in existing electricity supply. Figure 1-3 presents the way in which nighttime light data reflects fluctuations in light supply. The blue line is the SOL observed by the NPP-VIIRS [3] satellite and the orange line represents the trend of electricity supply in North Korea. Both of the data series show a decrease in 2015 and recovery after 2016.

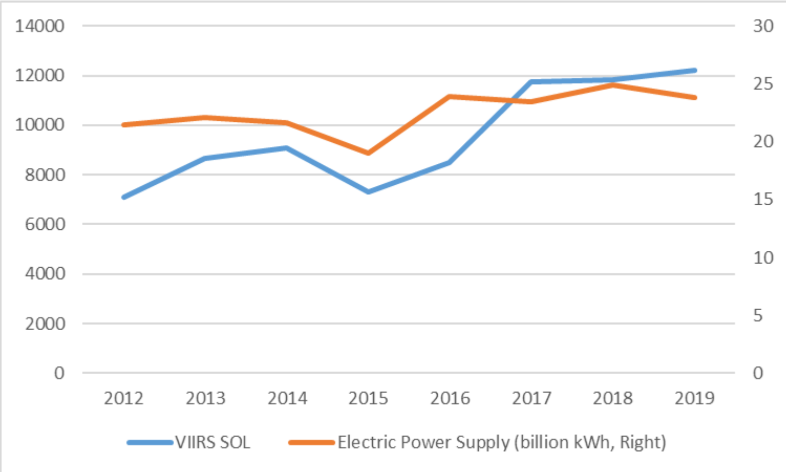

Figure 1-3. Adjusted Sum of Light and Power Supply

Source: Nighttime light data is from Earth Observation Group (Elvidge et al., 2021), and Electric power supply is from the Korean Statistical Information Service (KOSIS).

Second, the energy supply of North Korea is, in principle, a state monopoly, which is a typical feature of a planned economy. The electricity in North Korea is first supplied to the royal court economies, such as idolization sites and Kim Jong-un's vacation house, and then it is supplied to strategic national institutions such as munitions factories, steelworks, and important public facilities. Any surplus electricity is supplied for general industrial production and household consumption, but the amount is said to be restrictive, and a self-reliance strategy is emphasized in the energy sector, as

[3] This refers to Suomi National Polar-Orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) satellite, which is operated by the US NASA and National Oceanic and Atmospheric Administration (NOAA).

in other industries (박은진, 2018).

These aspects may raise doubts on the meaning of the nighttime light data of North Korea, implying that the data may merely reflect fluctuations in electricity supply and the decisions of the state, not the demand on electricity that represents public welfare or economic level. Moreover, noting that the overpass time of the NPP-VIIRS satellite is 1:30 AM, when most economic activities are likely to be inactive, this criticism may be valid.

Although these concerns are indeed reasonable, some changes in energy consumption have occurred in North Korea in recent years. Most notably, the Kim Jong-un regime emphasized electricity production as a top national priority and it appears to have been successful (이석기 et al., 2018). With increased electricity production, the energy consumption of industrial production sites and households is likely to have increased. Moreover, an increase in the supply of electricity itself may reflect the demand side. There have been amendments to laws regarding electric power generation allowing firms and institutions in North Korea to build small-sized power plants, generate electricity on their own, and sell the surplus electricity to other firms and institutions (박은진, 2018).

Also, household energy consumption is likely to have expanded. According to the World Bank’s World Development Indicator, only a quarter of the total population had access to electricity in 2009, but in 2018, 48% of the population had access to electricity, as shown in Figure 1-4. This is similar to the average proportion of the population with access to electricity in sub-Saharan Africa (46.7%) and higher than the average of low-income countries (41.8%) (World Bank, 2019). NPP-VIIRS nighttime light data are found to have positive correlations with socioeconomic variables, such as population and output, even in countries with low electricity consumption (Chen & Nordhaus, 2015). A growing number of studies are using NPP-VIIRS nighttime light data for predicting socioeconomic variables for countries with poor data ability (Wang et al., 2019; Zhao et al., 2020). Noting that North Korea has a similar or slightly better electricity usage rate, NPP-VIIRS nighttime light data may indicate general socioeconomic status in North Korea. To assess whether nighttime light data are correlated with socioeconomic performance in North Korea, the relationship between nighttime light and North Korea's welfare level is examined in the next section.

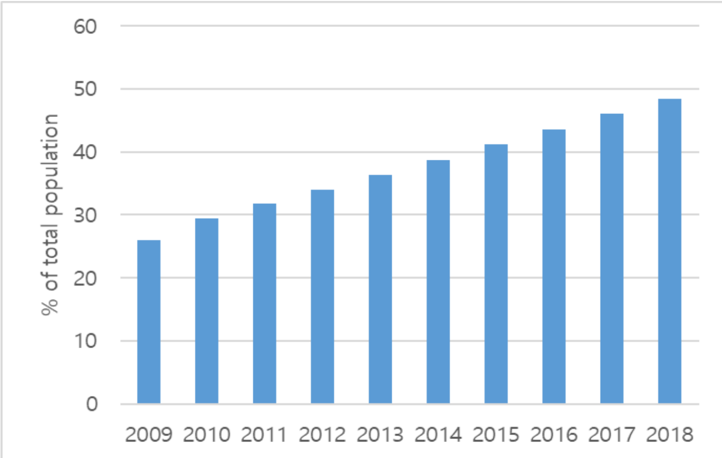

Figure 1-4. Access to Electricity

Source: World Development Indicators, World Bank

2.3.Nighttime Light and Welfare Level

Although many researchers have found strong relationships between nighttime light and a number of socioeconomic variables, the relationship may not hold in North Korea due to the aforementioned features of North Korean energy use. This section investigates the relationship between nighttime lights and welfare statistics using existing survey data at the provincial level.

North Korea conducted some nationwide surveys regarding population, health, education, living conditions, and other population considerations, with the help of international organizations. First, Sociodemographic and Health Surveys (SDHS) were conducted in

1993 and 2008, in collaboration with the United Nations Population Fund (formerly the United Nations Fund for Population Activities, UNFPA). There was a plan to conduct a third census survey in 2018 but has been delayed. The census contains information on population, economic activity, education, health, and living status by province, gender, and age. Second, four UNICEF Multiple Indicator Cluster Surveys (MICS) assess the development status of child and maternal health. North Korea participated in the survey in 1998, 2000, 2009, and 2017. Finally, Nutrition Surveys (NS) were conducted by the UN World Food Programme (WFP) to assess child and maternal health in 1997, 2002, 2004, 2006, and 2010.

According to 홍제환 et al. (2018), who tracked North Korean welfare status using the aforementioned surveys, North Korean welfare has continuously improved since 1998. The chronic malnutrition rate decreased from 62.3% in 1998 to 37% in 2004 and 9.1% in 2017. In addition, the proportion of underweight children decreased from 60.6% in 1998 to 23.4% in 2004 and 9.3% in 2017. The survey results on health status align with assessments of the North Korean economy, which experienced a serious food and malnutrition-related crisis in the 1990s and recovered slowly after the 2000s.

For the period when NPP-VIIRS nighttime light is observed, the NS in 2012, SDHS in 2014, and MICS in 2017 data exist. 2017 MICS data provides the most diverse information on North Korean households' welfare levels. Figure 1-5 shows the relationship between SOL and various welfare statistics at the province level that are surveyed in the 2017 MICS. SOL has a negative correlation of -0.71 with child malnutrition, which is measured as the percentage of the underweight children based on height. SOL also has a positive correlation of 0.74 with households' wealth level, which is measured by the International Wealth Index (IWI) estimated by 김석진 & 홍제환 (2019).[4] Among the information that is included in the construction of the IWI, SOL indicates a positive correlation of 0.86 with the proportion of in-house water sources and a negative correlation of −0.9 with the proportion of outdoor water sources. SOL also has a positive correlation of 0.7 with flush sanitation systems and a negative correlation of −0.72 with open-pit sanitation systems.

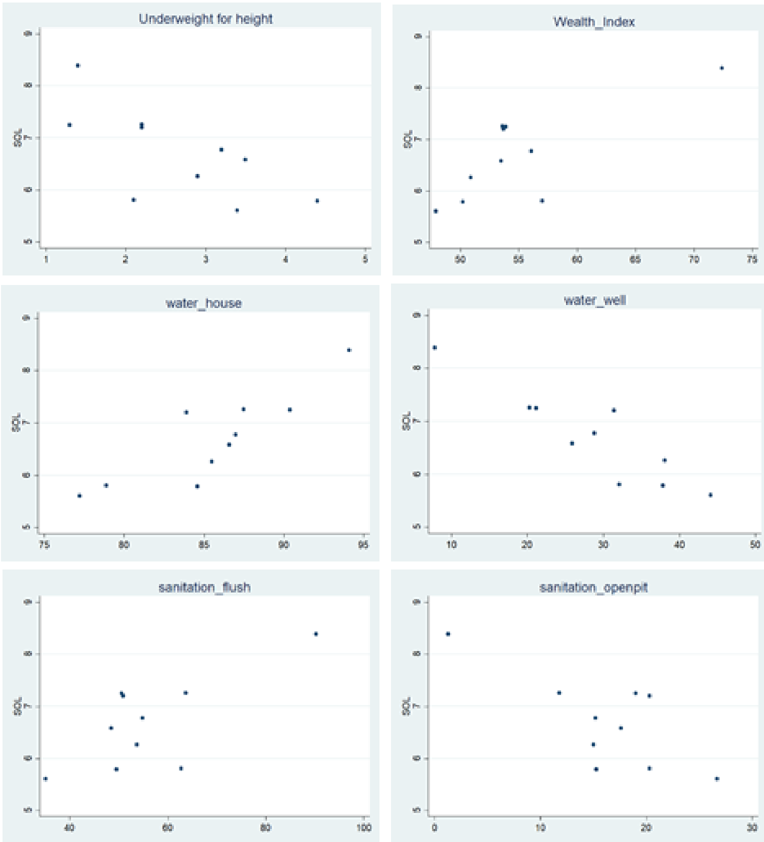

Figure 1−5. Cross-sectional Relationship of SOL and Welfare Statistics

Source: Survey statistics are from the 2017 DPR Korea MICS report (UNICEF), except for the wealth index. The wealth index is from 김석진 & 홍제환 (2019). SOL is from the VNL2 average masked nighttime light dataset of the NPP-VIIRS satellite in 2017.

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[4] The index assesses globally comparable household wealth and is based on various household wealth information reported in 2017 MICS data.

Few statistics are present in multiple surveys. Among them, the index of child malnutrition measured by under-height and underweight for age are present in 2012 NS and 2017 MICS data. Figure 1-6 shows the serial relationship between nighttime light and child malnutrition statistics at the province level in 2012 and 2017. Nighttime light shows an increase between 2012 and 2017, and the proportion of underweight children for age and under-height children for age decreases. However, the correlations between the change in SOL and change in the proportion of under-height and underweight children are low, with 0.37 and -0.05, respectively. The cross-sectional correlations between SOL level and the proportion of under-height and underweight children are much greater, with -0.68 and -0.89, respectively.

The result demonstrates that NPP-VIIRS nighttime light provides information for accurately explaining cross-sectional variations across regions, whereas correlations between the change in SOL and the change in regions' welfare status may be weak.

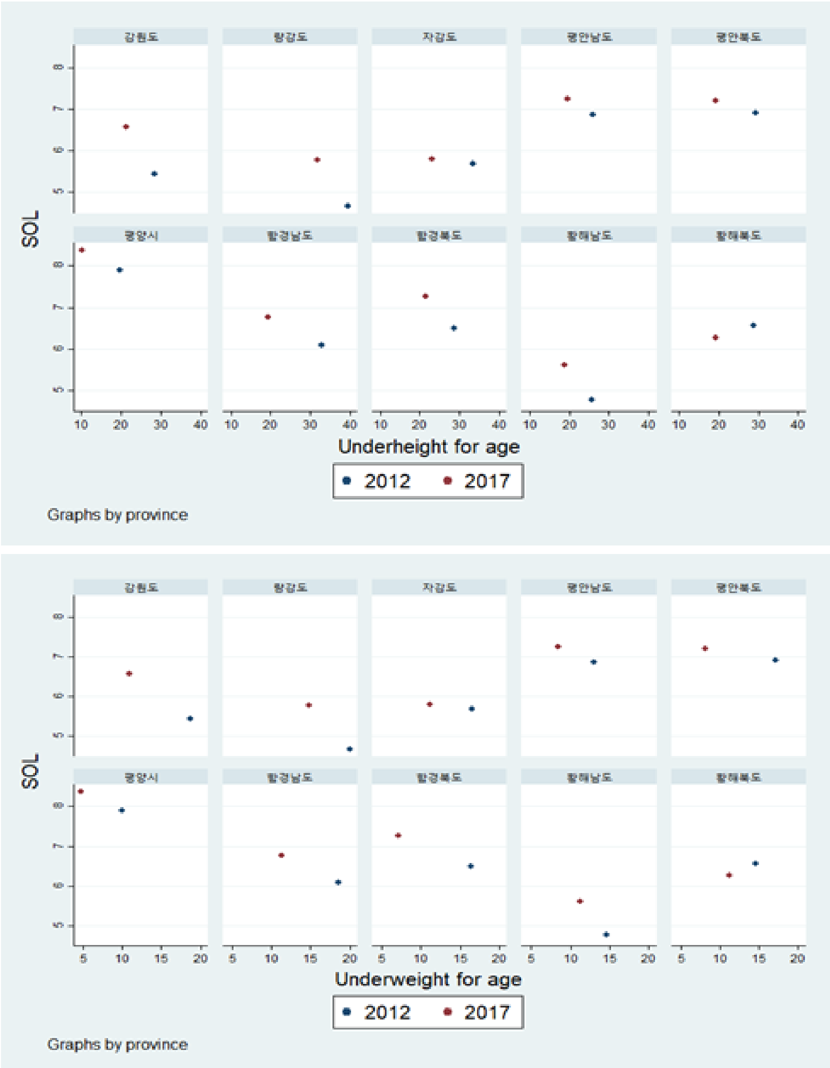

Figure 1-6. Serial Relationship between SOL and Welfare Statistics

Note: Underweight child for age measures the proportion of children who are less than 2 standard deviations for their age.
Source: Survey statistics are from the 2017 DPR Korea MICS report and the 2012 Nutrition Survey (WFP). SOL is from the VNL2 average masked nighttime light dataset of the NPP-VIIRS satellite in 2017.

3. Method and Data

3.1. Methodology

To estimate GRDP per capita and assess regional inequality, three steps are taken. First, the base GRDP per capita is calculated based on GDP and county-level urbanization rates. Second, the regression equation between base GRDP per capita and the SOL is estimated and the nighttime light-derived GRDP per capita is estimated by the fitted value. In this step, acknowledging the existence of the selection bias, the effect of electricity supply and special facilities are examined. Finally, the Gini coefficient and generalized entropy index, which measure regional inequality, are calculated to assess the trend of inequality and the generalized entropy index is decomposed into between and within province inequality.

As a first step, the base GRDP is calculated based on equation (1). It follows the serial trend of BOK estimates of GDP and takes the regional variation in urban population rate from the 2008 UN Census. Even though it is not an exact measure of regional economic level, much evidence confirms a strong correlation between the economic level and urbanization (Duranton, 2008). In some researches, the level of urbanization rate is used as a proxy for GDP per capita (Acemoglu et al., 2002; De Long & Shleifer, 1993). Thus, it may be regarded as a reasonable proxy for the regional economic level of North Korea in a situation where the county-level variable of any sort is limited.

$$Base\ GRDP\ per\ capita_{it} = \frac{GDP_t}{Total\ Population_t} * \frac{Urban\ Pop.Rate_i}{Average\ Urban\ Pop.Rate} \quad (1)$$

Next, the relationship between base GRDP per capita and SOL per unit area is estimated by the regression equation (2) y_{it} and x_{it} are the base GRDP per capita on SOL per $1km^2$ of the county i in year t. Time fixed effect is controlled for. Control for the county fixed effect is impossible since the cross-sectional variation in the dependent variable is time-invariant.

$$y_{it} = \beta_0 + \beta_1 x_{it} + \theta_t + \varepsilon_{it} \quad (2)$$

As mentioned in the previous section, there are a few concerns about using the nighttime lights data in research for the North Korean economy. Namely, serial inconsistency, left censoring, the tight electricity supply constraint, and the state control over the use of electricity. For the serial inconsistency problem, the NPP-VIIRS nighttime light data observed by a single satellite is used and the serial trend of the nighttime light data is excluded by including time fixed effect. For the left censoring problem, the selection bias test following Wooldridge (2010) is performed by including forward and backward selection terms in the regression equation. The forward selection term takes the value of 1 for counties that the value of SOL exists in the next period and 0 otherwise. The backward selection term takes the value of 1 for counties of which the lagged value of SOL exists and 0 otherwise. If there were a selection bias due to the censoring of light, the selection bias terms are expected to have positive and significant value.

The effect of electricity supply is tested by including control variables of precipitation level and the number of electricity firms. If the brightness of the nighttime light is mainly determined by the supply of electricity, the coefficient of SOL will be reduced or become insignificant when electricity supply is controlled for. Lastly, to test the effect of state control over electricity usage, the number of special facilities such as monumental places, public facilities, hotels, etc. are controlled for. Lights from the special facilities are reflected both in the data generation process and in regression analysis. The lights from pixels that include these special facilities are excluded from the summation of county-level lights. And as a proxy for the unidentified special facilities, the number of special facilities is used as a control variable.

Lastly, the GRDP per capita of counties in North Korea is estimated by the fitted value of the regression equation and inequality indices based on GRDP per capita are calculated for each year. The measures of inequality include the Gini coefficient and generalized entropy index following equations in (3) and (4), respectively. y_i and y_j are the GRDP per capita of county i and j, n is the number of counties, and μ is the average GRDP per capita each year. The generalized entropy index has the parameter α that decides to which class more weight is imposed. In this research, $\alpha=0$ so that more weight is put on the lower class. Generalized entropy index with $\alpha=0$ is calculated by the equation (5). The generalized entropy index can be decomposed by the within-group and between-group inequality as in equation (6). The first term represents the within-group inequality and the second term represent between-group inequality. k represents the number of groups, n_k represents the number of counties in group k, and λ_k represents the average GRDP per capita of group k. The level of inequality is decomposed by the within and between province inequality.

$$Gini = \frac{1}{2\mu n^2}\left(\sum_i \sum_j |y_i - y_j|\right) \tag{3}$$

$$\mathrm{GE}(\alpha) = \frac{1}{\alpha^2-\alpha}\left(\frac{1}{n}\sum_i \left(\frac{y_i}{\mu}\right)^{\alpha} - 1\right), \quad \alpha = 0,1,2 \tag{4}$$

$$GE(0) = \frac{1}{n}\sum_i \log\left(\frac{\mu}{y_i}\right) = \sum_k \frac{n_k}{n} GE(0)_k + \sum_k \frac{n_k}{n}\log\left(\frac{1}{\lambda_k}\right) \tag{5}$$

$$GE(0) = \sum_k \frac{n_k}{n} GE(0)_k + \sum_k \frac{n_k}{n}\log\left(\frac{1}{\lambda_k}\right) \tag{6}$$

3.2. Data

The nighttime light data explained in section 2 are aggregated at the county level and converted to SOL per 1km^2 . The nighttime light used is the annual VNL V2 average-masked version that can be downloaded from the Earth Observation Group website. The administration boundary of the county level of North Korea is acquired from Open Street Map(OSM) database and has been adjusted to match the list of counties in the 2008 UN Census. To sort out the noise or non-economic lights, some pixels are filtered out according to the following rules. First, lights within the 2km from the borders are excluded from the summation except for the pixels identified as a city center to rule out spread lights from China and South Korea. The pixels of the city center are identified by the SMOD dataset from the Global Human Settlement database which categorizes every 1km^2 pixel of the world into various settlement types. Second, the pixels with special facilities are excluded as mentioned above. Special facilities are identified by the Places of Interest dataset from the OSM database.

The area of each county is calculated from the ArcGIS program. The population is derived from Gridded Population of the World, v4. It provides the estimated population of every 1km^2 of the world by distributing census data proportional to pixel-level land area. The dataset provides the North Korean gridded population in 2000, 2005, 2010, 2015, 2020. The periods in between have been linearly interpolated. For annual GDP, the estimate of the Bank of Korea on real GDP is used and it is converted to international dollar using the PPP exchange rate by IMF. The urban population rate is derived from the 2008 UN Census data. The precipitation level of 24 regions in North Korea is downloaded from KOSIS. For the regions where regional precipitation data don' t exist, the province-level averages of precipitation are applied. The number of electricity firms is the number of electricity firms in each county that are reported in the official media of North Korea during 2000−2012. The data is acquired from Korea Institute for Industrial Economics and Trade (KIET). Table 1−1 shows summary statistics of the variables used in the regression analysis.

Table 1−1. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ln(SOL)	1,094	2.60	1.72	-2.69	8.28
Urban pop. Rate	1,416	0.47	0.22	0.14	1
Population	1,416	141488	197825	24774	2488767
Area	1,416	668.9	414.9	16.4	2263.0
ln(Electric firms)	1,416	-1.80	2.58	-4.61	1.79
ln(Precipitation)	1,416	6.82	0.35	5.86	7.70
ln(Special facilities)	1,416	-4.11	1.60	-4.61	4.79

Note: 0.01 is added in the number of electricity firms and special facilities before taking a log to avoid missing varialbe

4. Results

4.1. Estimation of GRDP per capita

As a first step of estimating the GRDP per capita of North Korea, county−level−based GRDP per capita is calculated. The base GRDP per capita follows a serial trend of the Bank of Korea’s estimate on North Korean GDP and the cross−sectional variation is proportional to the urbanization rate from the 2008 UN Census. As shown in Figure 1−7, regional variation is identical across periods since the urbanization rate is time−invariant.

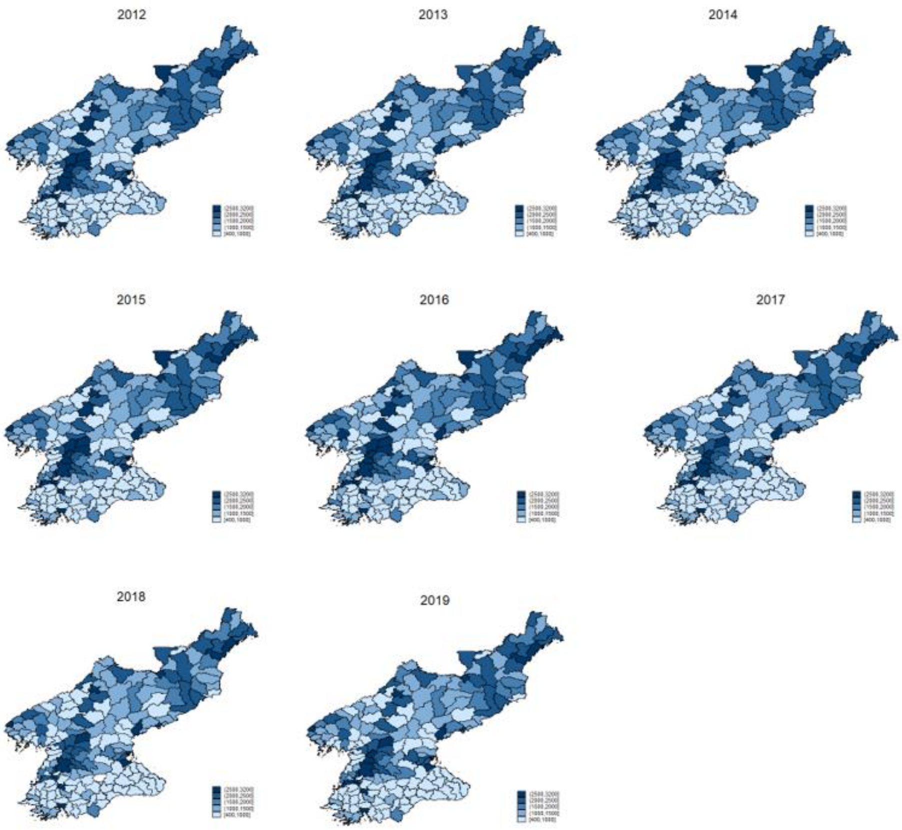

Figure 1-7. Base GRDP per capita

Table 1-2 presents the regression result of base GRDP per capita on SOL per $1km^2$. Column (1) is the baseline result and it is estimated that a 1% increase in SOL per $1km^2$ is correlated with a 0.134% increase in GRDP per capita. The quadratic specification is tested in column (2) and appears to be insignificant. Columns (3) and (4) test the presence of selection bias by including selection terms in the regression (Wooldridge, 2010). As selection bias terms are found to be insignificant, this implies that no selection bias is present.

Columns (5) and (6) test whether nighttime light is significant when controlling for the electricity supply. Although the annual fluctuation of electricity supply is controlled by year fixed effects, cross-sectional variation in electricity supply may still be present.

The number of electricity firms and the regional precipitation level are included to control for such effects. If the nighttime light contains information identical to the supply of electricity, the SOL per 1km^2 term is expected to become insignificant or show a decrease in the coefficient when electricity supply is controlled for; however, the coefficients in columns (5) and (6) indicate little change or a slight increase. In column (7), the number of light pixels that include special facilities is used as a proxy for state-managed facilities. When the variable is controlled for, the coefficient remains significant but the magnitude decreases. This implies that the SOL per 1km^2 partially includes light from special facilities.

Table 1-2. Regression Result of Base GRDP per capita on SOL per 1km^2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln(SOL per 1km^2)	0.134***	0.131***	0.132***	0.131***	0.133***	0.140***	0.111***
	(0.013)	(0.026)	(0.013)	(0.014)	(0.013)	(0.012)	(0.015)
ln(SOL per 1km^2) Sq.		-0.000					
		(0.002)					
Forward selection			0.019				
			(0.065)				
Backward selection				0.029			
				(0.065)			
ln(# of electric firms)					0.017		
					(0.012)		
ln(precipitation)						-0.415***	
						(0.098)	
ln(special facilities)							0.056***
							(0.014)
Constant	7.812***	7.823***	7.784***	7.744***	7.838***	10.784***	7.942***
	(0.061)	(0.108)	(0.096)	(0.092)	(0.064)	(0.688)	(0.055)
Observations	1094	1094	956	952	1094	1094	1094
R-squared	0.29	0.29	0.29	0.28	0.30	0.34	0.33

Note: 1) Robust standard error clustered for the county is reported in the parentheses, * $p< 0.1$, ** $p<0.05$, *** $p<0.01$

The nighttime light-derived GRDP per capita is estimated by using the fitted value of the result in column (1) of Table 1-2. Figure 1-8 presents a scatter plot between based GRDP per capita and fitted GRDP per capita in 2012 and 2019, indicating that regions with similar base GRDP per capita have differing fitted GRDP per capita reflecting the level of SOL per 1km^2 , although a positive correlation exists between the two.

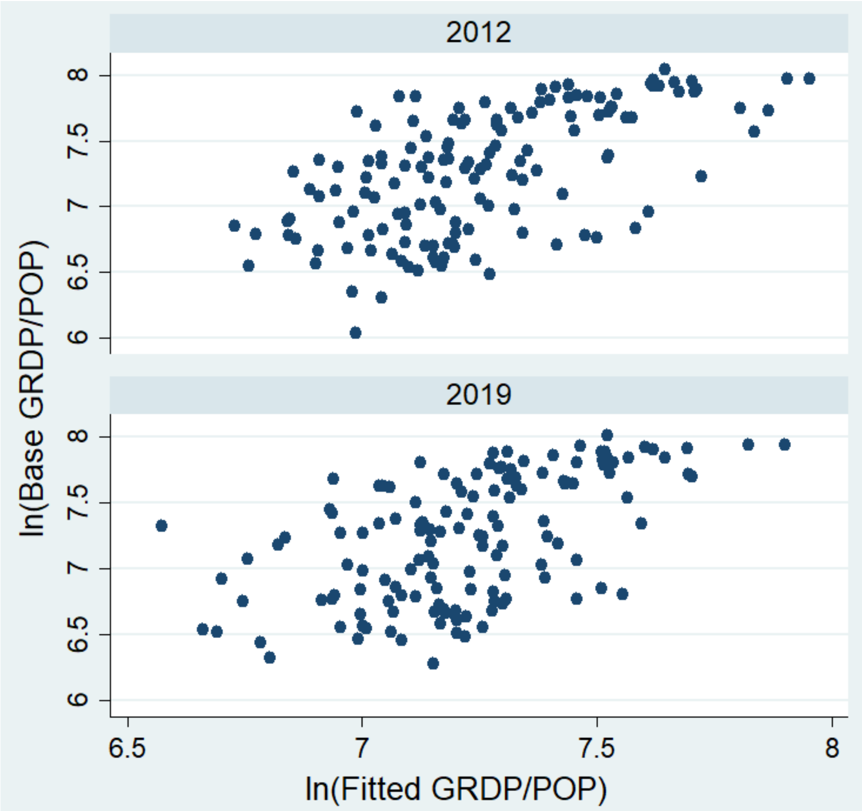

Figure 1-8. Relationship between Base GRDP per capita and Fitted GRDP per capita

The GRDP per capita each year is presented in Figure 1-9. On average, the regions that demonstrated high average GRDP per capita in 2012-2019 are Sinuiju city (2,774 USD), Pyongyang city (2,645 USD), and Cheonlima-gun (2,402 USD). Pyongyang indicates a high level of GRDP per capita, as expected, with Sinuiju city indicating a slightly higher GRDP per capita than Pyongyang.[5]

Dividing the period into before and after sanctions, Sinuiju, Pyongyang, Cheonlima-gun, Songlim, and Kaesong are the regions with the highest GRDP per capita prior to sanctions in 2012-2016, representing the major trade hubs or industrial cities. In 2017-2019, the rank of Kaesong city decreases to 11 from five in 2012-2016. This is because the Kaesong industrial complex was shut down in 2016 due to North Korea' s nuclear tests and missile launches. Wonsan city became the fifth highest city in 2017-2019, replacing Kaesong city, and the rest of the top five cities are identical to 2012-2016.

The white regions represent counties in which no nighttime lights are detected. In 2012-2013 and 2015, South Hwanghae Province shows the highest proportion of counties missing light. 40%-60% of counties in the province show no detected light. In 2014, South Hawnghae Province is the second-highest in the proportion of the missing SOL counties and North Hawnghae Province is the highest. However, the trend changes after 2016 when sanctions on North Korea intensified. The provinces that show the highest proportion of absent SOL counties are Ryanggang Province in 2016-2017 and Jagang Province in 2018-2019, which are both located on the North Korea-China border wherein the regional economy crucially depends on trade with China. This indirectly indicates the effect of sanctions.

[5] The results are similar for SOL per $1km^2$. Pyongyang is the second highest in terms of SOL per area, with 2.8 nW/cm^2 /sr per $1km^2$, and Sinuiju city shows the brightest SOL per area, with 4.1 nW/cm^2 /sr per $1km^2$.

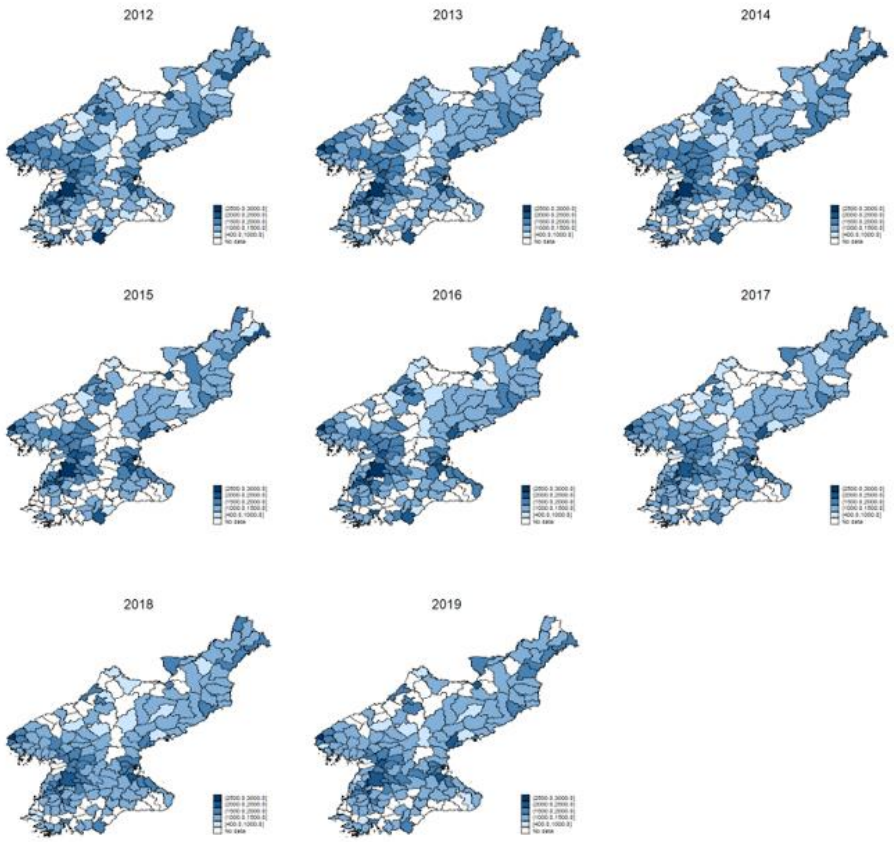

Figure 1-9. GRDP per capita Estimated from Nighttime Lights

Figure 1-10 presents a box plot graph of GRDP per capita each year with the lowest level of GRDP per capita regarded as the censoring threshold for missing data. Censoring was highest in 2015, when the electricity supply was the lowest within the research period. The disparity between regions appears to increase prior to sanctions and decrease following the implementation of sanction in 2017.

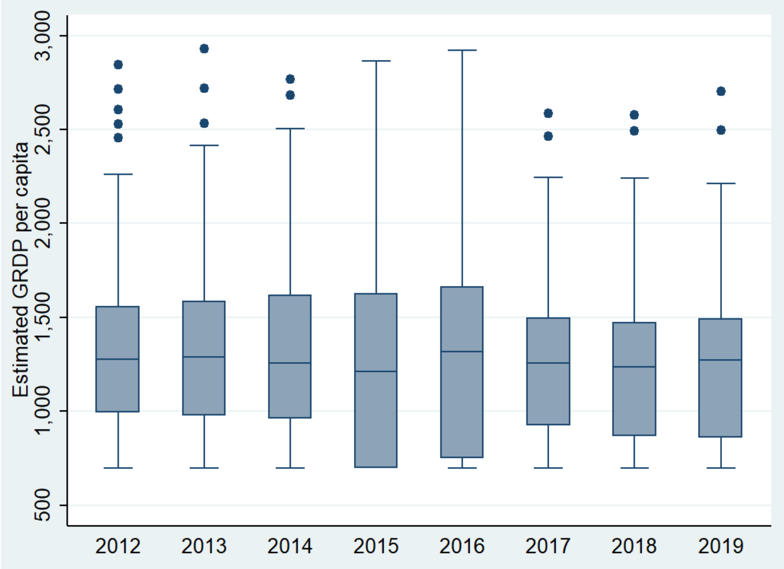

Figure 1-10. Box Plot of GRDP per capita at the County Level

Note: The lowest level of GRDP per capita estimated, 698 USD, is regarded as a censoring threshold and is assigned to the counties with missing nighttime light data.

Figure 1-11 presents the trend of GRDP per capita and the logged value of SOL per $1km^2$ of the capital and metropolitan cities. As noted above, Sinuiju and Pyongyang show a high level of GRDP per capita. Wonsan shows a relatively high increase in SOL and GRDP per capita during the sanction period. Haeju city, the capital of South Hwanghae, shows the lowest level of GRDP and SOL per capita among the capital and metropolitan cities; a similar trend to the proportion of missing nighttime light counties within the province.

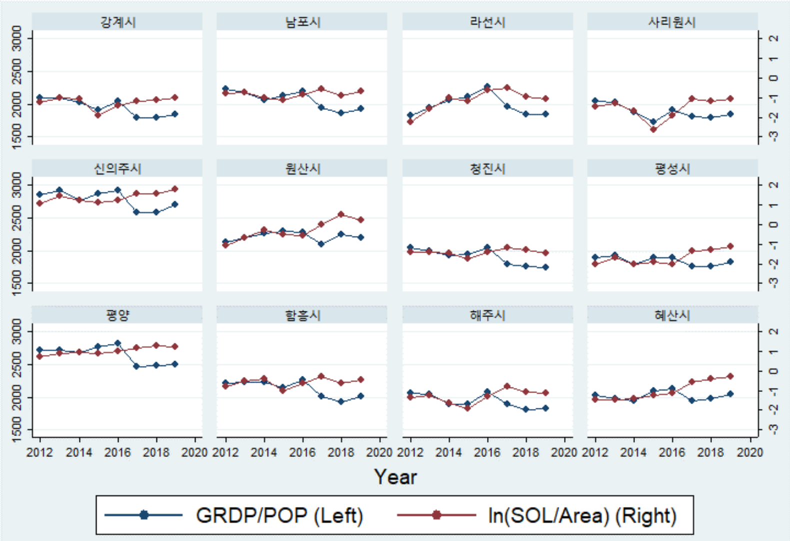

Figure 1-11. The Trend of GRDP per capita and SOL per capita in Capital Cities and Metropolitan Cities

4.2. Regional Disparity of North Korea

Figure 1-12 shows regional disparity at the province level, measured as GRDP per capita or IWI, relative to that of Pyongyang. The comparison is made between the result of this research and other studies' estimates of the province-level economy. Estimates from this research are presented in several ways. First, the average GRDP per capita is calculated at the province level using the censored sample that applies the lowest level of estimated GRDP per capita to the missing counties. Second, the average GRDP per capita is calculated using the truncated sample excluding missing counties. Third, GRDP per capita is calculated at the provincial level by applying SOL per 1km^2 calculated at the province level to the estimated regression equation in column (1) of Table 1-2. In this version of estimates, neither truncation nor censoring occurs. Estimates from other studies are IWI estimated by 김석진 & 홍제환 (2019) and GRDP per capita by 이석 (2015). All figures are transformed to proportions relative to Pyongyang.

Among the three versions of this assessment's results, the non−truncated and non−censored versions reveal the largest gap between Pyongyang and other cities and the smallest gap in the truncated sample version. The average level of economic status of other provinces is 64% that of Pyongyang for GRDP per capita of the non−truncated, non−censored version, whereas they are 70% and 77% for GRDP per capita with the censored and truncated samples, respectively. In the truncated sample version, GRDP per capita level is overestimated, since missing counties are neglected. The gap between Pyongyang and other provinces of the censored sample is similar to the gap evaluated by IWI of 김석진 & 홍제환 (2019) and all versions show less gap than the estimates by 이석 (2015), in which the GRDP of provinces per capita, other than Pyongyang, is only 46% that of Pyongyang.

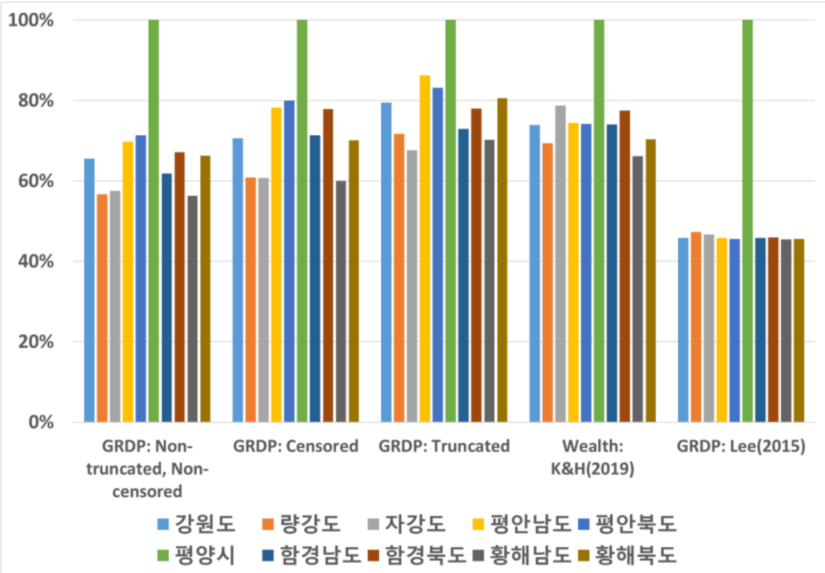

Figure 1−12. Provincial Level Economic Status Relative to Pyongyang

Note: 1) Non−truncated, non−censored GRDP is per capita GRDP calculated at the province level, censored GRDP is the average GRDP per capita of counties at the province level, with minimum estimated GRDP per capita as a censoring point, and truncated GRDP excludes missing counties in the average. Wealth:K&H(2019) is the international wealth index from 김석진홍제환 (2019) and GRDP:Lee(2015) is GRDP per capita from 이석 (2015).

2) All are transformed to proportion relative to Pyongyang

Finally, Table 1-3 presents various inequality indices and the decomposition result of the generalized entropy index each year. On average, regions at the 90^{th} percentile have 2.2 times higher GRDP per capita relative to regions at the 10^{th} percentile. The region with the highest GRDP per capita level, which is Sinuiju city, has 3.28 times higher GRDP per capita than that of the regions in the 10^{th} percentile GRDP per capita. Gini coefficient is 0.199 and GE(0) is 0.065 on average.[6] The Gini coefficient and GE(0) level seems to decrease under the sanction regime. The average Gini coefficient is 0.208 for 2012-2016 and 0.184 for 2017-2019, representing an 11.2% decrease. Also, the average Generalized Entropy Index (GE(0)) is 0.071 for 2012-2016 and 0.057 for 2017-2019, which is a 20% decrease. The trend is similar for the raw SOL per $1km^2$ data, although the magnitude of the decrease is smaller. Gini coefficient and GE(0) for SOL per area decreases by 3.5% and 10.1%, respectively, under sanctions compared to the previous sanction period.

The GE(0) allows the decomposition of inequality to within and between-group inequality. The decomposition at the province level shows that 87.3% of inequality stems from within-province inequality, and between-province inequality only accounts for 12.6% of total inequality. The decomposition result based on SOL per $1km^2$ also finds that 86.8% of the inequality derives from within-province. This is striking because previous studies have mostly emphasized and analyzed the between-province inequality. The result indicates the importance and necessity of county-level analyses in studying the regional disparity of North Korea.

[6] Direct comparison between the Gini coefficient at the different regional scale is inappropriate; however, as a rough reference for comparison, the Gini coefficient based on the province level GRDP per capita for 2012-2019 is 0.166 by the author's calculation based on KOSIS regional GDP per capita data.

Table 1−3. Measures of Inequality

Year	p90/p10	Max/p10	Gini	GE(0)	Within Province	Between Province
2012	1.98	2.80	0.199	0.065	85.7%	14.3%
2013	2.02	3.37	0.200	0.066	87.4%	12.6%
2014	2.00	3.83	0.200	0.065	87.3%	12.7%
2015	2.77	2.66	0.228	0.084	87.6%	12.4%
2016	2.55	3.27	0.212	0.075	90.8%	9.2%
2017	1.94	2.93	0.182	0.055	86.2%	13.8%
2018	2.04	3.49	0.182	0.055	85.8%	14.2%
2019	2.14	3.93	0.189	0.060	87.4%	12.6%
Total	2.18	3.28	0.199	0.065	87.3%	12.7%

5. Conclusions

This research estimated the GRDP per capita of counties in North Korea using nighttime light data. For the estimation, the base GRDP per capita, as a proxy for true GRDP per capita level, is calculated based on the urban population rate. Then the nighttime light derived GRDP per capita is estimated as the fitted value from the regression equation of base GRDP per capita on SOL per 1km^2 . In the regression, the existence of selection bias and the effect of electricity supply constraints and lights from the special facilities are tested.

The estimated GRDP per capita fully employs a cross−sectional variation of nighttime lights, but the serial trend follows the estimate of the Bank of Korea. Thus, the result provides further implications regarding the cross−sectional variation between counties rather than on the serial trend. However, if there are significant serial changes in the SOL level relative to other countries, the serial trend of GRDP per capita of that county represents such changes.

The main results are threefold. First, popular trade hubs and industrial cities such as Sinuiju, Pyongyang, Cheonlima-gun, and Kaesung show a high level of GRDP per capita and a difference is apparent in the regional distribution of light prior to and following the implementation of sanctions. Although the cities that show a high level of GRDP per capita are similar before and after sanctions, the regions in which nighttime light is not observed are not. Before sanctions, inland provinces near the North and South Korean border, such as North and South Hwanghae province, show the highest proportion of unlit counties. Following sanctions, Jagang and Ryanggang province near the North Korea-China border show the highest proportion of unlit counties.

Second, the average level of province-level economic status is about 64-70% of that of Pyongyang. The comparison, based on a non-truncated and non-censored version of province-level GRDP per capita, indicates that the economic status of other provinces is about 64% that of Pyongyang, with a range varying from 56% of Pyongyang (South Hwanghae province) to 71% of Pyongyang (North Pyongan province). Based on the censored sample, the relative level of other provinces is 70% of Pyongyang on average.

Finally, a large gap in GRDP per capita is evident between counties, and the majority of the regional inequality in North Korea stems from within-province. Various measures of inequality are calculated, revealing that 90^{th} percentile region' s GRDP per capita is 2.2 times higher than that of the 10^{th} percentile region. The highest GRDP per capita is 3.28 times that of the 10^{th} percentile region. Decomposition of the Generalized Entropy Index by province reveals that 87.3% of the inequality is due to within-province inequality, and between-province inequality only occupies 12.7%. The result confirms the importance of analyses at the county level.

Chapter 2. Determinants of the North Korean Regional Economy and the Effect of Sanctions in the Kim Jong-un Era

1. Introduction

Researchers assessed North Korean economic performance in the 2010s as successful before the implementation of sanctions. Many were doubtful of the Bank of Korea's estimates of North Korea's growth rate, which demonstrated minimal growth in the 2010s.[7] The main reason for such suspicion is the ample evidence of growth in marketization and trade in North Korea.

The development of the market in the North Korean economy is rapid and extensive. The share of household income from the informal sector amounts to over 70% of total household income (Kim, 2017). Various markets are developing, such as service, housing, labor, and goods markets (이석기 et al., 2014). Even the formal sector depends on such markets for survival under the continuous self-reliance strategy of the North Korean state, which requires meeting targets without supplying the inputs for production. In 2013, the North Korean government partially institutionalized the market activities of firms through a reform plan entitled the "Socialist Corporate Responsibility Management System." The plan enhanced companies' autonomy regarding establishing the production targets, inputs purchase, and product sales. Overall, North Korea's informal sector increases national investment, improves productivity and resource allocation efficiency, and contributes to the national finance (임강택, 2013; 조한범 et al., 2016).

[7] The Bank of Korea's estimate of the North Korean GDP growth rate is 0.9% on average for 2010–2016.

Another important factor that is considered the main driver of North Korean economic growth is expanding its export trade. During the 2010-2016 period, exports from North Korea grew 180%, from 1.5 billion USD in 2010 to 2.8 billion USD in 2016, according to the Korean Trade Investment Promotion Agency (KOTRA, 2013). Import also grew 130% during that time, from 2.6 billion USD to 3.7 billion USD. The export of mineral products led to this growth, representing up to 58.8% of total exports in 2013. Since the mining sector procures a high level of foreign currency acquisition rates, North Korea would have acquired a massive amount of foreign currency through mineral exports (장형수 & 김석진, 2019). Increased trade may also result in externalities that expand the market further since trade growth extends the autonomy of low-level economic agents (임수호 et al., 2017).

For most countries, economic performance largely depends on industrial production. For North Korea, the role of the formal industrial sector in the economy is considered insubstantial. 김석진 (2007) conclude that North Korean industrial policy in the 2000s was unsuccessful, judging by the low level of manufacturing product exports and imports of capital goods, and 김종선 et al. (2010) assert a similar view. 이석기 et al. (2010) indicate that industrial recovery in North Korea has been highly unbalanced, as only industries related to the defense industry recovered in the 2000s. However, in the Kim Jong-un era, some studies report the partial success of North Korea's industrial policy, which prioritizes energy production and modernizes production facilities while refraining from massive investments in heavy industries. 이석기 et al. (2018) carefully present evidence of recovery in the machinery and food processing industries, based on media coverage of North Korea. 최장호 et al. (2017) find that import composition reflects the regime's industrial policy of production facilities' improvements. 정은이 et al. (2020) assume a more positive perspective, asserting that firms' operation rate has risen to nearly 50%, based on a case study on 303 North Korean firms.

Due to restricted data access, most of the aforementioned research takes a qualitative approach based on interviews with North Korean defectors or descriptions of a few available statistics. By introducing a novel set of data such as nighttime light data and other geographical information rarely used in the field, this research empirically analyzes the determinants of the North Korean regional economy in the Kim Jong-un era. It considers the market, trade, and formal industries as factors that potentially contribute to the regional economy.

This study also analyzes the impact of sanctions and the channel of transmission in the North Korean economy. North Korea is enduring the severest sanctions since 2017. In 2017, the UN Security Council (UNSC) resolved to prohibit the export of mineral products. Two subsequent UNSC resolutions further prohibited the export of garment products and the import of capital goods. The UNSC also reduced the import limit of refined petroleum products and ordered the repatriation of existing dispatched workers. Although assessing the effect of sanctions is crucial, only indirect evidence, such as a decrease in trade volumes and price trends, is available. This research estimates the effect of sanctions on the North Korean economy and its transmission channel.

The main findings of the research are threefold. First, market and trade are the main contributing factors to the regional economy. Every quartile increase in market size increases regional nighttime light by 2.5%-7.5%. Every quartile increase in the proximity to trade hubs increases regional nighttime light by 0.9%-7.8%, with the effect concentrated at the top quartile. Second, the implementation of sanctions reduces the brightness of the nighttime light by 5.4% and lit area density by 7% each year. Lastly, the impact of sanctions varies across regions to a large extent. Sanctions damage the regional economy or welfare mainly through a reduction in trade and market activities. Thus, regions near the trade hubs or with large markets that appreciated the benefit before sanctions are damaged more severely. In contrast, regions near the wholesale market appear to better cope with sanctions relative to other regions.

The contributions of the study are also threefold. First, it overcomes the data constraints impeding empirical research on North Korean regions by using nighttime light data, map−based data, satellite−based data, North Korean media data, and other sources to investigate the effect of market, trade, and formal industries comprehensively and quantitatively. Second, it expands the understanding of the regional economy of North Korea. Previous regional level studies have mostly leaned on case studies or a few provincial level statistics. This study constructs a dataset that is suitable for performing comprehensive research at the county level. Lastly, it quantitatively estimates the effect of sanctions and investigates the transmission channel of sanctions.

The remainder of this research is organized into three sections. Section 2 explains the construction of the dataset, providing descriptive details of the regional distribution of economic resources, followed by the methodology applied. The results and discussions are presented in section 3, and section 4 concludes.

2. Data and Method

2.1. Data

This study uses nighttime light as a proxy to measure the regional economic status or welfare level. Nighttime light data is observed by the Suomi National Polar−Orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS), via the NPP−VIIRS satellite, operated by the US NASA and National Oceanic and Atmospheric Administration. The data is provided in 15 arc−

seconds (approximately 500 m at the equator) spatial resolution, making sub-national research possible. The data is objective in quality and thorough in coverage since it is observed by satellite and is being actively used in conducting economic research of data-poor countries. Many studies have examined the relationship between nighttime light and socioeconomic variables such as urbanization rate, GDP, built area density, electricity consumption, and other concerns (Ma, Zhou, Pei, et al., 2014; Ma, Zhou, Wang, et al., 2014). In particular, Bruederle and Hodler (2018) confirmed that nighttime light data could correlate with welfare statuses, such as school attendance rate, toddler mortality rate, and household wealth, even in countries with low electricity accessibility.

Nighttime light emission has been used as a proxy for GDP per capita in various studies (Shenoy, 2018; Hodler and Raschky, 2014; Pinkovskiy and Sala-I-Martin, 2016), and even as a major instrument to improve the quality of GDP statistics. Henderson, Storeygard, and Weil (2012), pioneering researchers that began using nighttime light data in economics, estimated GDP based on nighttime light and derived the optimal weight between national GDP statistics and nighttime light derived GDP. Nordhaus and Chen (2015) took a similar approach, investigating the validity of the estimation result by bootstrap. They concluded that nighttime light data provides abundant cross-sectional information and can help improve the GDP statistics of countries with low statistical abilities. Nighttime light data is also used in research on North Korea to descriptively review the trends of economic status in North Korea and its major cities (김규철, 2017; 김정아 & 천상현, 2020).

Nonetheless, there are a few concerns with nighttime light data in researching the North Korean economy. First, the change in nighttime light may represent electricity supply and not economically meaningful electricity demand because North Korea has long suffered from electricity supply shortages. Second, the energy supply of North Korea is, in principle, a state monopoly. The electricity in North Korea is supplied first to the royal court economies, including idolization sites and Kim Jong-un's vacation house, and then to important national strategic institutions. Surplus electricity is supplied for general industrial production and household consumption, but the amount is reportedly minimal, and self-reliance in energy production is emphasized, as in other industries (박은진, 2018). Lastly, the overpass time of the NPP-VIIRS satellite is 1:30 AM, when most economic activities are likely to be inactive. These aspects raise doubts that the data could merely reflect fluctuations of electricity supply and the decisions of the state, not the demand for electricity that represents welfare or the economic level of the public.

Although these concerns are reasonable, evidence has demonstrated that regional nighttime light correlates with regional welfare levels as shown Figure 1-5 of the previous Chapter. World Bank statistics also indicate that electricity use is increasing among the general public in North Korea. According to the World Bank's World Development Index, the proportion of the population with access to electricity rapidly grew from 25% in 2009 to 48% in 2018, which is higher than the average among low-income countries (41.8%) or sub-Saharan African countries (46.7%). Previous research indicates a positive correlation between NPP-VIIRS nighttime light and socioeconomic variables, even in countries with low electricity consumption (Chen & Nordhaus, 2015). Therefore, NPP-VIIRS nighttime light data could signify general socioeconomic status in North Korea.

Since the above result does not fully rule out the possibility of bias, various adjustments and robustness tests are conducted. First, to sort out the noise or non-economically related light, the location of special facilities, such as monuments, statues, stadiums, and other sites of national interest, are identified using the OpenStreetMap (OSM) database and the light emitted from these locations is excluded. In addition, the light within 2 km from the borders is excluded from the summation (other than pixels identified as a city center) to rule out light spread from China and South Korea. Second, robustness of the results is tested by controlling the state's policy or investment on regions via news reports on each region, or by using lit area density as another dependent variable. Lit area density, which could be considered an extensive margin, rules out the effect of special facilities, which are likely always to be bright. Lastly, the effect of annual electricity supply is controlled by the fixed effects, and cross-sectional electricity supply is controlled by the regional precipitation level and the number of power plants.

A county-level database containing various economic and geographic information is created for independent variables, as presented in Table 2-1. For the market, two variables are used. First, the number of vendors in official markets from 홍민 et al. (2016) is used to measure market size. Another variable to measure domestic market activity is proximity to major wholesale markets. Connectivity to a domestic distribution hub may be an important factor, as imported and produced commodities are first collected in major wholesale markets and transported for redistribution after that (홍민, 2016). ArcGIS software calculates the distance to the closest major wholesale markets for each county through the road system. The list and locations of national scale wholesale markets is based on 홍민 (2016), and proximity is measured as the average ground travel distance to the closest wholesale market from each pixel of counties' central areas, which ArcGIS calculates.

The proximity to trade hubs is measured to investigate the effect of trade on the regional economy. Trade hubs are international ports (남포항, 송림항, 해주항, 원산항, 흥남항, 청진항, 나진항, 선봉항) and land-based important customs (신의주철도세관, 혜산세관, 무산세관, 회령세관, 남양세관, 원정세관). The land-based customs listsare based on 2012 freight flows reported in 서종원 and

노상우 (2014). For formal sector industries, the number of firms in mining, light, and heavy industries noted in official North Korean media in 2000-2012, weighted by the number of field visits made during 2008-2012, is used. The Korea Institute for Industrial Economics and Trade (KIET) provides data on media coverage.

In addition to the aforementioned main variables of interest, various control variables are used. The road length per area, the number of mainline train stations per area, and the number of pixels containing special facilities control for infrastructure. Road length is calculated from the OSM database. The number of stations is from the North Korean train database of the Korean Transport Institute. Special facilities include memorials, monuments, hotels, universities, hospitals, and other regional and national interest sites, which are identified using the points of interest dataset in the OSM database.

Regional precipitation levels and the number of electric power plants control for electricity supply. Power plants are those mentioned in official media, and is provided by KIET. The precipitation levels of 27 regions from the Korea Statistical Information System (KOSIS) are used for precipitation. A province−level average is used in the regions for which direct precipitation level is not observed.

Other socioeconomic variables included are population, urban rate, and media coverage. Population is from World Gridded Population database and urban rates is from 2008 UN Census. The media coverage variable is the number of times each region is mentioned in the Rodong Newspaper each year after 2015 and is constructed based on the archive of KCNA watch. Geographic variables include average elevation, area, dummies for provincial capitals, and the North Korea-China border areas. The ArcGIS program calculates the average elevation and counties’ areas. The capital cities dummy includes Nampo and Rasun metropolitan cities in addition to the provincial capitals.

Table 2-1. The List of Variables

Category	Variable	Description
Night light	Sum of Lights (SOL)	The sum of lights within each county.
	Lit area density	The proportion of lit pixels in each county.
Market	Market size per capita	The number of vendors per capita (홍민 et al., 2016).
	Proximity to the wholesale market	The closest distance to a wholesale market (옥전시장, 수남시장, 채하시장, 삼일시장, 갈마시장, 구천시장, 산성시장).
Trade	Proximity to trade hub	The closest distance to trade hubs (남포항, 송림항, 해주항, 원산항, 흥남항, 청진항, 나진항, 선봉항, 혜산세관, 무산세관, 회령세관, 남양세관, 원정세관, 신의주철도세관).
Industry (Formal sector)	Formal firms per capita (by sector)	The number of firms by sector (light, heavy, mining) mentioned in formal media in 2001–2012, weighted by the number of field visits during 2008–2012 (KIET).
Infrastructure	Mainline train station density	The number of mainline train station/Area (교통연구원 DB).
	Road density	The length of major roads/Area (OSM DB).
	Special facilities	Memorials, monument, hotels, universities, hospitals, and other sites of national interest (OSM DB).
Electricity Supply	Electric power plant	The number of electric power plants mentioned in formal media in 2001–2012 (KIET).
	Precipitation	Annual precipitation (KOSIS).
Other socioeconomic variables	Population	Population (Gridded Population World DB) with interpolation.
	Urban rate	Urban population/Total population (2008 UN Census).
	Media coverage	노동신문 coverage count (KCNA watch archive).
Geographical location	Elevation	Calculated with ArcGIS software.
	Area	Calculated with ArcGIS software.
	Capital cities	평양, 남포, 신의주, 강계, 혜산, 라선, 청진, 함흥, 원산, 해주, 사리원, and 평성.
	Border	DPRK–China border counties

2.2. Descriptive Statistics

This section describes the economic geography of North Korean regions. Figure 2-1 presents the distribution of the market size. The region with the biggest market size is Chongjin, followed by Pyongyang and Hamhung. In general, South Pyongan province has a large market size, followed by South Pyongan and North Hamkyong provinces. Raynggang province has a small market size.

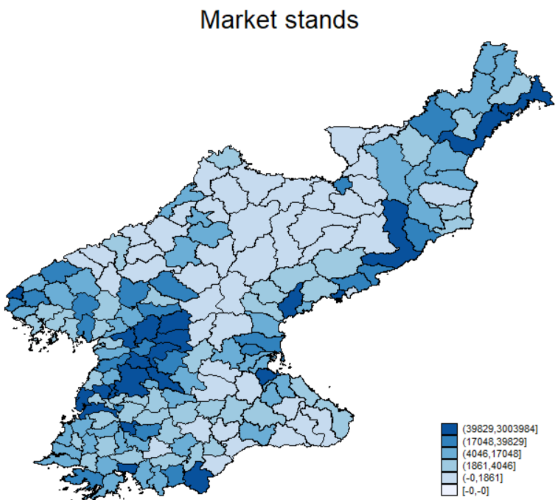

Figure 2-1. The Regional Distribution of Market Stands

Note: The values are in logged term and 1 is added before taking a log.

Figure 2-2 presents the location of the major wholesale markets and each region' s proximity. This reveals that regions near the North Korea-China border are inferior in terms of access to wholesale markets, except for those near Sinuiju. Conversely, North and South Pyongan provinces and South Hwanghae provinces show superior access to the wholesale markets.

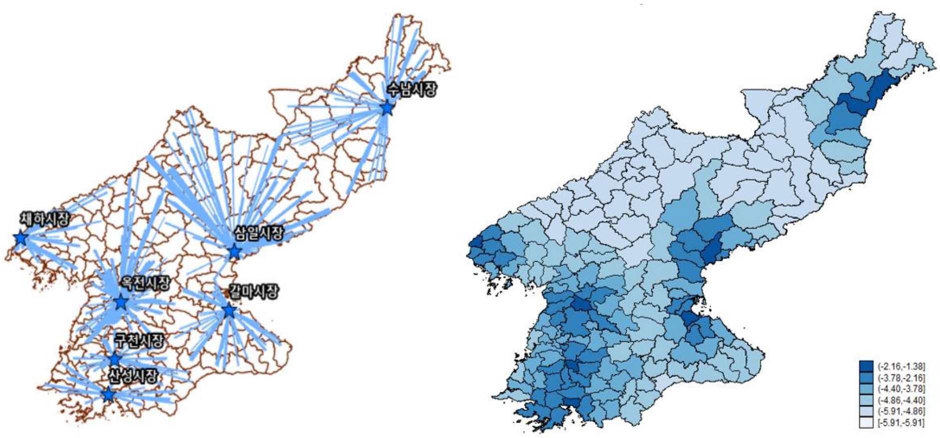

Figure 2-2. Location of and Proximity to the Wholesale Markets

Note: The values subtract the logged average distance to wholesale markets.

Figure 2-3 presents the location of trade hubs and each region's proximity. Since many land-based customs centers are in North Hamkyong province, the distance to the trade hubs from counties within the province is short in general. In contrast, in counties of Jagang province, access to trade hubs is difficult because although it borders China, there are no major customs, and the road infrastructure is relatively inferior.

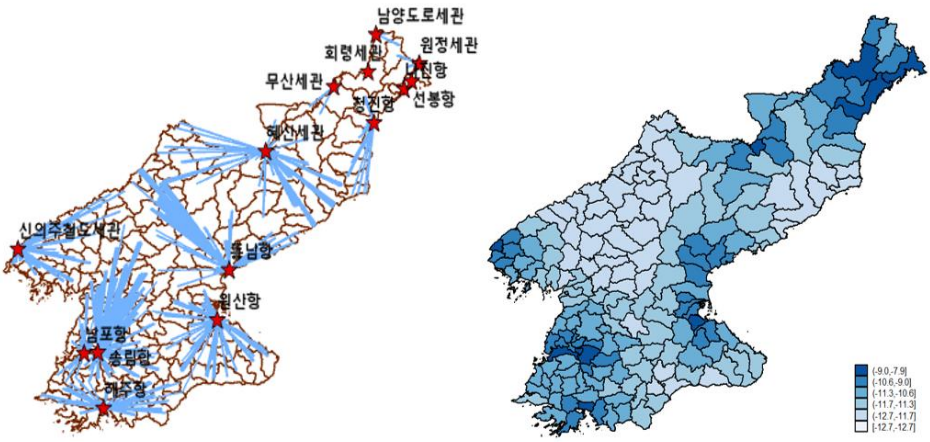

Figure 2-3. Location of and Proximity to the Trade Hubs

Note: The values subtract the logged average distance to trade hubs.

Figure 2-4 presents the distribution of formal sector firms by industry. Mining firms are concentrated in regions with abundant minerals. Light industry firms are concentrated in regions such as Pyongyang, Sinuiju, Rason, Kaesong, and the heavy industry firms are densely located in regions such as Chongjin, Suncheon, Hamhung, and Kaesong.

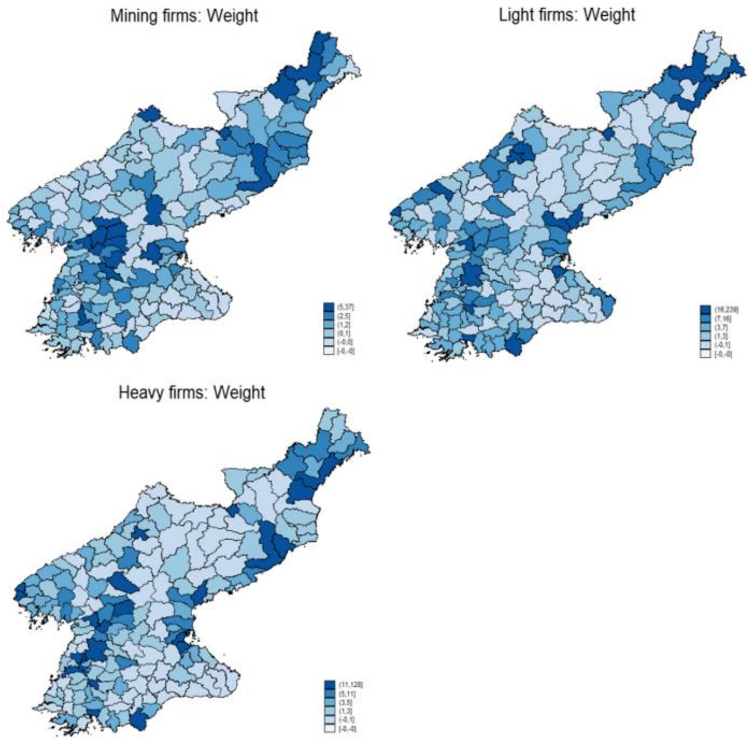

Figure 2-4. The Distribution of Official Firms by Industry

Note: The values are in logged term and 1 is added before taking logs.

A known censoring problem exists in North Korea. About 20%-30% of counties each year have no observed nighttime light. As shown in Figure 2-5, there are differences in the market size and the number of formal firms between lit and unlit counties. This implies a possible selection bias due to nighttime light censoring and should be considered in empirical modeling. Figure 6 presents these notable differences.

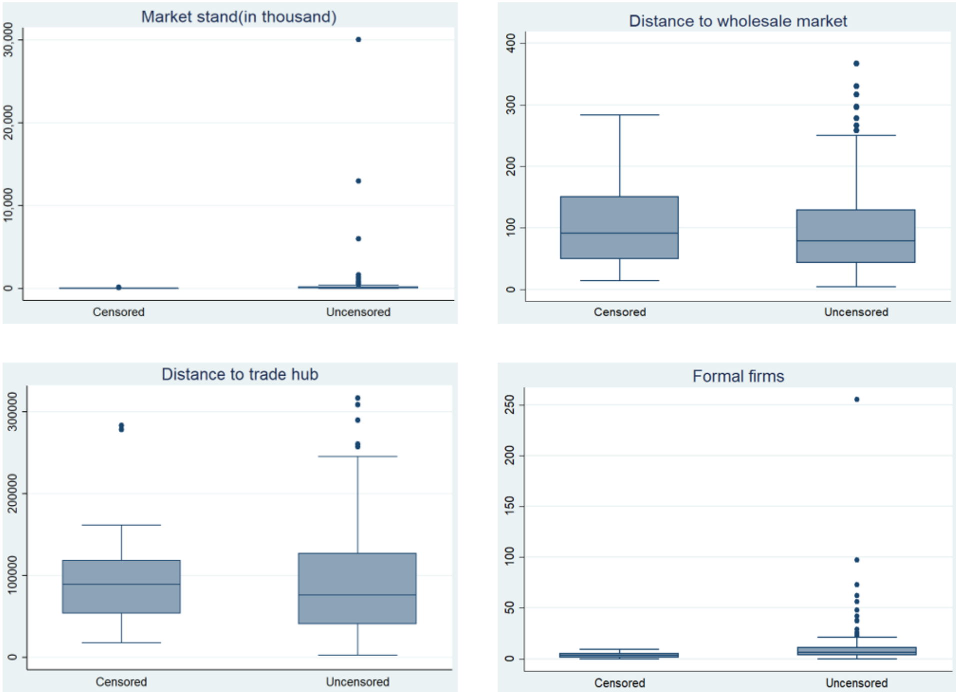

Figure 2-5. The Ranges of Main Variables of Censored and Uncensored Counties

Table 2-2 shows the summary statistics of the dependent variables, explanatory variables, and other control variables. Only SOL, lit area density, precipitation, population, and media coverage variables are time-varying, and other variables are time-invariant. 0.01 and 0.0001, values less than the minimum observed values, are added to SOL and lit area density before taking logs to avoid truncation.

Table 2-2. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ln(SOL)	1,416	0.97	3.38	−4.61	8.28
ln(Lit area density)	1,416	−4.23	3.01	−9.21	0.00
ln(Market stand)	1,416	8.45	2.35	−4.61	14.92
ln(Prox. to wholesale market)	1,416	−4.28	0.91	−5.91	−1.38
ln(Prox. to trade hub)	1,416	−11.10	0.98	−12.67	−7.88
ln(Mining firms)	1,416	−0.90	2.43	−4.61	2.57
ln(Light firms)	1,416	0.65	2.07	−4.61	5.00
ln(Heavy firms)	1,416	0.20	2.34	−4.61	4.67
Road density	1,416	0.32	0.22	0.08	2.15
Station density	1,416	0.05	0.06	0	0.31
ln(Special facilities)	1,416	−4.11	1.60	−4.61	4.79
ln(Electric firms)	1,416	−1.80	2.58	−4.61	1.79
ln(Precipitation)	1,416	6.82	0.35	5.86	7.70
ln(Population)	1,416	11.58	0.66	10.12	14.73
Urban pop. ratio	1,416	0.47	0.22	0.14	1
ln(Media coverage)	790	3.03	1.06	−4.61	6.66
Capital cities	1,416	0.07	0.25	0	1
Border	1,416	0.14	0.35	0	1
ln(Elevation)	1,416	5.46	1.16	2.16	7.34
ln(Area)	1,416	6.31	0.69	2.80	7.72

Note: 1 is added before taking a log for market stand, the number of mining firms, light firms, heavy firms, and electric firms to avoid missing data. For Lit density, 0.0001 is added before taking a log.

2.3. Methodology

Since all of the explanatory variables and most of the control variables are time-invariant, the fixed effects model with county-based fixed effects is not applicable. Thus, the model controls for time fixed effects only, in addition to controlling for county-specific heterogeneity with as many control variables as possible. The empirical specification is shown below in equation (1).

$$y_{it} = \beta_0 + \beta_1 y_{it-1} + \beta_2 M_i + \beta_3 T_i + \beta_4 F_i + \delta Z_{it} + \theta_t + \varepsilon_{it} \qquad (1)$$

where y_{it} is SOL per area or lit area density and lagged term is included to assess the growth effect; M_i contains market size, measured as the number of market vendors and the proximity to wholesale markets; T_i is the proximity to trade hubs; F_i includes the number of military, mining, light, and heavy industry firms; and Z_{it} includes the control variables introduced in section 2.1.

To assess the effect of sanctions, equation (2) is estimated. Time fixed effect is excluded, and sanction dummy, which takes a value of 1 for 2017–2019 and 0 otherwise, is included. The annual electricity supply is additionally controlled for. The coefficient for S_t estimates the average annual effect of sanctions.

$$y_{it} = \beta_0 + \beta_1 y_{it-1} + \beta_2 M_i + \beta_3 T_i + \beta_4 F_i + \beta_5 S_t + \delta Z_{it} + \varepsilon_{it} \qquad (2)$$

The channel of sanctions' effect is estimated by equation (3), where X_{it} is a vector of market size, proximity to the wholesale markets, proximity to trade hubs, and the number of formal sector firms. If $\beta_2 \neq \beta_2 + \beta_3$, this indicates that sanctions changed the effect of the driving forces of the North Korean regional economy. As sanctions prohibit or restrict trade, areas near trade hubs should reveal direct sanction impact. If the prohibition on trade exacerbates the trade deficit and decreases income and supply of industrial inputs, market activity and industrial production will shrink, triggering a vicious cycle in the economy. If sanctions caused such impact, $\beta_2 < \beta_2 + \beta_3$ will hold.

$$y_{it} = \beta_0 + \beta_1 y_{it-1} + \beta_2 X_{it} + \beta_3 (X_{it} * S_t) + \delta Z_{it} + \theta_t + \varepsilon_{it} \qquad (3)$$

To deal with a potential censoring bias, the Tobit model is also applied. The model assumes that the error term follows $N(0, \sigma^2)$ and incorporates the probability that the observation is censored. The Tobit model estimates the coefficients of the log-likelihood function in equation (4) using a maximum likelihood estimation method, in which y_c is the censoring level and $\Phi(.)$ is the CDF of the normal distribution.

$$\ln L = \sum_{y_i = y_c} log\left\{\frac{1}{\sigma}\Phi\left(\frac{y_i - X_i\beta}{\sigma}\right)\right\} + \sum_{y_i > y_c} log\left\{\frac{1}{\sigma}\Phi\left(\frac{y_i - X_i\beta}{\sigma}\right)\right\} \quad (4)$$

3. Results

3.1. The Determinants of Regional Economic Growth

Table 2-3 presents the baseline results for the determinants of the regional economy. Market size and proximity to trade hubs indicate significant positive effects in the OLS and the Tobit model. Industrial variables are insignificant for all sectors. Since the operation rate of formal sector firms in North Korea is low, it is plausible that formal sectors do not contribute to the regional economy. However, since the NPP-VIIRS nighttime lights are observed at 1:30 AM when industrial activities are mostly inactive, a possibility remains that the effects of formal sectors on the regional economy are underestimated. Among control variables, precipitation level and electricity firms exhibit positive effects in the OLS model but not in the Tobit model. The urban population rate has a positive effect, and capital cities show negative effects.

Table 2-4 presents the average marginal effects of market, trade, and industry variables. Based on the Tobit model, 10% growth in market size results in 0.22% growth in SOL, and 10% growth in proximity to trade hubs results in 0.18% growth in SOL. Other factors have insignificant average marginal effects. As the empirical theory predicts, the coefficients of the marginal effects of the Tobit model are smaller than those of the OLS model.

Table 2-3. Baseline Regression Result

	(1)	(2)	(3)	(4)	(5)	(6)
		OLS			Tobit	
ln(Market)	0.144***		0.140***	0.172***		0.167***
	(0.041)		(0.041)	(0.058)		(0.059)
ln(Prox. wholesale)	0.040		0.037	0.080		0.080
	(0.069)		(0.068)	(0.083)		(0.082)
ln(Prox. trade)	0.147**		0.154***	0.121*		0.137*
	(0.060)		(0.058)	(0.072)		(0.070)
ln(Mining firms)		0.026	0.016		0.042	0.028
		(0.055)	(0.056)		(0.078)	(0.078)
ln(Light firms)		0.028	0.052		0.089	0.111
		(0.080)	(0.075)		(0.103)	(0.098)
ln(Heavy firms)		0.070	0.017		0.023	-0.038
		(0.077)	(0.075)		(0.099)	(0.098)
L.ln(SOL)	0.770***	0.784***	0.768***	0.951***	0.968***	0.949***
	(0.027)	(0.027)	(0.028)	(0.040)	(0.039)	(0.039)
Station density	0.969	1.287	1.033	0.835	1.211	0.882
	(0.859)	(0.907)	(0.881)	(1.079)	(1.125)	(1.114)
Road density	-0.184	-0.218	-0.218	-0.121	-0.222	-0.214
	(0.273)	(0.279)	(0.283)	(0.306)	(0.329)	(0.330)
ln(Electric firms)	0.223***	0.152	0.219**	0.172	0.105	0.168
	(0.083)	(0.093)	(0.087)	(0.109)	(0.121)	(0.114)
ln(Precipitation)	0.389**	0.294*	0.387**	0.209	0.130	0.215
	(0.179)	(0.176)	(0.182)	(0.234)	(0.234)	(0.238)
Capital cities	-0.412*	-0.181	-0.455*	-0.639**	-0.411*	-0.714**
	(0.234)	(0.191)	(0.240)	(0.288)	(0.236)	(0.297)
Border	-0.242	-0.220	-0.267	-0.273	-0.312	-0.321
	(0.163)	(0.145)	(0.164)	(0.203)	(0.194)	(0.207)
ln(Area)	0.083	0.073	0.094	0.182	0.162	0.188
	(0.156)	(0.167)	(0.163)	(0.209)	(0.225)	(0.222)
ln(Population)	0.035	0.212	-0.007	-0.101	0.121	-0.140
	(0.143)	(0.147)	(0.156)	(0.192)	(0.204)	(0.217)
Urban pop. ratio	1.030***	1.109***	0.997***	0.908**	1.058***	0.938**
	(0.335)	(0.336)	(0.345)	(0.412)	(0.403)	(0.426)
ln(Elevation)	0.002	-0.075	-0.002	-0.033	-0.122	-0.036
	(0.089)	(0.090)	(0.090)	(0.116)	(0.120)	(0.118)
ln(Special facilities)	0.151	0.128	0.136	0.061	0.031	0.043
	(0.186)	(0.199)	(0.187)	(0.227)	(0.244)	(0.230)
Constant	-3.309*	-4.959**	-2.839	-1.589	-3.456	-1.095
	(1.959)	(2.061)	(2.117)	(2.414)	(2.616)	(2.678)
Observations	1239	1239	1239	1239	1239	1239
R-squared	0.76	0.76	0.76			
sigma				2.046***	2.061***	2.045***
				(0.127)	(0.127)	(0.126)

Note: Robust standard errors clustered for counties in the parentheses; * P < .1, ** P < .05, *** P < .01.

Table 2-4. The Average Marginal Effects of Baseline Results

	(1) OLS	(2) Tobit
ln(Market)	0.140***	0.022***
	(0.041)	(0.008)
ln(Prox. wholesale)	0.037	0.011
	(0.068)	(0.011)
ln(Prox. trade)	0.154***	0.018**
	(0.058)	(0.009)
ln(Mining firms)	0.016	0.004
	(0.056)	(0.010)
ln(Light firms)	0.052	0.015
	(0.075)	(0.013)
ln(Heavy firms)	0.017	-0.005
	(0.075)	(0.013)
Observations	1239	1239

Note: Robust standard errors clustered for counties in the parentheses; * P < .1, ** P < .05, *** P < .01.

As the variance of market vendors and proximity to trade hubs are sizable, the impacts converted in realistic terms are large. Figure 2-6 illustrates the partial effects of every quartile increase in market size and proximity to trade hubs based on the Tobit model. For the first and last quartile, partial effects from increases from the 5th percentile to the 25th percentile and from the 75th percentile to the 95th percentile are measured to rule out the effects of outliers.

An increase in market size from the 5th percentile to the 1st quartile, from the 1st quartile to the 2nd quartile, from the 2nd quartile to the 3rd quartile, and from the 3rd quartile to the 95th percentile cause 4.8%, 2.5%, 6.4%, and 7.5% increases in SOL, respectively. An increase in the proximity to trade hubs from the 5th percentile to the 1st quartile, from the 1st quartile to the 2nd quartile, from the 2nd quartile to the 3rd quartile, and from the 3rd quartile to the 95th percentile cause 1.7%, 0.9%, 1.4%, and 7.8% increases in SOL, respectively.

The partial effect of a quartile increase in trade hub proximity shows a stark contrast between the last quartile and lower quartiles. While an increase from the 3rd quartile to the 95th percentile in trade hubs proximity causes a 7.8% increase in SOL, the effects are much smaller in the lower quartiles. This implies that although the extent of trade involvement measured as the proximity to trade hubs has a positive effect throughout, the effect is mainly concentrated in regions located near trade hubs. In contrast, an increase in market size indicates a noticeable effect on the regional SOL in every quartile. This implies that the effect of market size is universal in North Korean regions. On average, a quartile increase in market size causes a 5.3% increase in SOL.

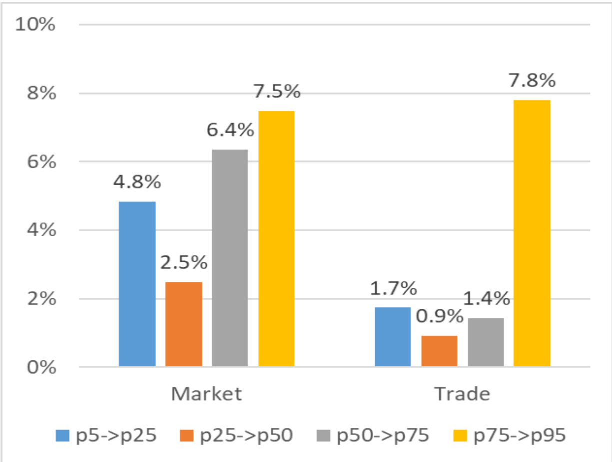

Figure 2-6. Partial Effects of Market and Trade

3.2. The Effect of Sanctions

This section analyzes the effect of sanctions, estimating the magnitude of sanctions' effect by adding the sanction dummy rather than the year fixed effects term. Annual electricity supply is included to control for electricity supply since year fixed effects are excluded. The partial effect of the sanction dummy measures the average annual effect of sanctions on the regional SOL level. The results in Table 2-5 indicate that the sanction period dummy has a significant and negative coefficient both in the OLS and Tobit models. In addition, the coefficient of the annual electricity supply is significant and positive in both models. The results for other variables are similar to the baseline results.

Table 2-5. Regression Result for the Sanction Effect

	(1)	(2)	(3)	(4)	(5)	(6)
		OLS			Tobit	
Sanction	−0.232*	−0.250*	−0.229*	−0.413**	−0.430**	−0.408**
	(0.129)	(0.129)	(0.129)	(0.169)	(0.170)	(0.169)
ln(Elec. Supply)	0.236***	0.166*	0.229**	0.189*	0.120	0.180
	(0.086)	(0.095)	(0.090)	(0.113)	(0.124)	(0.118)
ln(Market)	0.146***		0.141***	0.177***		0.171***
	(0.043)		(0.043)	(0.059)		(0.060)
ln(Prox. wholesale)	0.065		0.060	0.102		0.102
	(0.069)		(0.069)	(0.083)		(0.082)
ln(Prox. trade)	0.123**		0.131**	0.103		0.119*
	(0.061)		(0.059)	(0.073)		(0.071)
ln(Mining firms)		0.017	0.005		0.033	0.016
		(0.056)	(0.058)		(0.079)	(0.080)
ln(Light firms)		0.037	0.057		0.102	0.121
		(0.083)	(0.078)		(0.106)	(0.102)
ln(Heavy firms)		0.082	0.032		0.038	−0.023
		(0.081)	(0.079)		(0.103)	(0.102)
Observations	1239	1239	1239	1239	1239	1239
R-squared	0.75	0.75	0.75			
sigma				2.084***	2.099***	2.083***
				(0.128)	(0.129)	(0.128)

Note: 1) Robust standard errors in parentheses are clustered for counties. 2) Results for the control variables are omitted. * P < .1, ** P < .05, *** P < .01.

Converted to the partial effect based on the Tobit model, as presented in Table 2-6, sanctions decrease the regional SOL level by 5.4% each year on average. The results from the previous section reveal that a quartile increase in the market size increases regional SOL by 5.3% on average. Hence, the effect of sanctions can be considered comparable to reducing the market size to the lower quartile, representing a scale that cannot be ignored.

Table 2-6. Average Marginal Effect of Regression for the Sanction Effect

	(1) OLS	(2) Tobit
Sanction	-0.229*	-0.054**
	(0.129)	(0.023)
ln(Market)	0.141***	0.023***
	(0.043)	(0.008)
ln(Prox. wholesale)	0.060	0.013
	(0.069)	(0.011)
ln(Prox. trade)	0.131**	0.016*
	(0.059)	(0.009)
ln(Mining firms)	0.005	0.002
	(0.058)	(0.011)
ln(Light firms)	0.057	0.016
	(0.078)	(0.014)
ln(Heavy firms)	0.032	-0.003
	(0.079)	(0.014)
Observations	1239	1239

Note: Robust standard errors clustered for counties in the parentheses; * P < .1, ** P < .05, *** P < .01.

3.3. Transmission Channels of the Sanction Effects

Table 2-7 presents the results for the analysis of sanctions' transmission channels. Interaction terms between sanction dummy and market, trade, and industry variables are included to estimate the sanction regime's effects on the regional economy. The market size has a positive effect on SOL. Still, this effect diminishes under sanctions in both the OLS and Tobit model, except for the result in column (6), wherein all variables and interaction terms are included in the Tobit model. Similarly, the proximity to trade hubs has a positive effect, decreasing under sanctions in all specifications and models. In contrast, proximity to wholesale markets has a positive effect only under the sanction period in both models. This can be interpreted as domestic logistics gaining importance under the crisis.

Industry variables appear insignificant regardless of the sanction regime in the Tobit model. As previously noted, it is possible that nighttime light fails to measure industrial production activities due to the NPP−VIIRS overpass time. Thus, it is more appropriate to interpret the region's general welfare or economic status rather than derive implications on the production status of formal industrial sectors. The results may imply that formal sector wages contribute little to household wealth, regardless of the sanction regime. The most common official wage is 1,000–3,000 North Korean Won. In contrast, the most common side income from the informal sector is over 1,000,000 North Korean Won, according to successive surveys of North Korean defectors by the Institute for Peace and Unification Studies (천경호 et al., 2020).

Table 2-7. Regression Result of the Sanction Transmission Channel

	(1)	(2)	(3)	(4)	(5)	(6)
		OLS			Tobit	
ln(Market)	0.177***		0.184***	0.217***		0.222***
	(0.038)		(0.038)	(0.050)		(0.051)
ln(Market) X Sanc.	-0.079**		-0.104*	-0.113**		-0.138
	(0.036)		(0.056)	(0.055)		(0.089)
ln(Prox. wholesale)	-0.053		-0.057	-0.048		-0.046
	(0.080)		(0.080)	(0.097)		(0.097)
ln(Prox. wholesale) X Sanc.	0.219**		0.219**	0.299**		0.295**
	(0.089)		(0.093)	(0.117)		(0.123)
ln(Prox. trade)	0.208***		0.224***	0.199**		0.225***
	(0.067)		(0.064)	(0.080)		(0.077)
ln(Prox. trade) X Sanc.	-0.147**		-0.168**	-0.188**		-0.210**
	(0.072)		(0.074)	(0.091)		(0.093)
ln(Mining firms)		0.056	0.024		0.090	0.043
		(0.066)	(0.065)		(0.090)	(0.088)
ln(Mining) X Sanc.		-0.068	-0.018		-0.108	-0.034
		(0.099)	(0.105)		(0.124)	(0.133)
ln(Light firms)		0.098	0.111		0.181	0.190
		(0.092)	(0.085)		(0.124)	(0.118)
ln(Light) X Sanc.		-0.164	-0.141		-0.213	-0.180
		(0.108)	(0.111)		(0.143)	(0.147)
ln(Heavy firms)		0.020	-0.071		-0.031	-0.140
		(0.087)	(0.084)		(0.115)	(0.114)
ln(Heavy) X Sanc.		0.116	0.205*		0.125	0.235
		(0.091)	(0.105)		(0.119)	(0.144)
Observations	1239	1239	1239	1239	1239	1239
R-squared	0.76	0.76	0.76			
sigma				2.042***	2.059***	2.040***
				(0.126)	(0.127)	(0.126)

Note: 1) Robust standard errors in parentheses are clustered for counties. 2) Results for the control variables are omitted. * P < .1, ** P < .05, *** P < .01.

Table 2-8 presents the average marginal effects of the main variables, depending on the sanction regime. According to the Tobit model, a 10% increase in market size causes a 0.28% increase in SOL before sanctions but not after. The average marginal effect of the market before sanctions is increased compared to the baseline result, which does not distinguish between sanction periods. Similarly, a 10% increase in the proximity to trade hubs increases SOL by 0.29% before sanctions, and the effect disappears under sanctions. The magnitude of the average marginal effect of proximity to trade hubs is also greater than the baseline result. In contrast, a 10% increase in proximity to wholesale markets contributes to a 0.4% increase in SOL only under sanctions.

Table 2-8. Average Marginal Effects by Sanction Regime

		(1) OLS	(2) Tobit
ln(Market)	Before	0.185***	0.028***
		(0.037)	(0.008)
	After	0.071	0.011
		(0.062)	(0.013)
ln(Prox. wholesale)	Before	-0.046	-0.005
		(0.082)	(0.012)
	After	0.190**	0.040*
		(0.087)	(0.022)
ln(Prox. trade)	Before	0.227***	0.029**
		(0.065)	(0.013)
	After	0.068	0.004
		(0.076)	(0.014)
ln(Mining firms)	Before	0.027	0.006
		(0.066)	(0.012)
	After	0.016	0.003
		(0.090)	(0.017)
ln(Light firms)	Before	0.110	0.024
		(0.085)	(0.016)
	After	-0.047	-0.002
		(0.101)	(0.018)
ln(Heavy firms)	Before	-0.064	-0.017
		(0.085)	(0.015)
	After	0.123	0.012
		(0.099)	(0.019)
		1239	1239

Note: Robust standard errors clustered for counties in the parentheses; * P<.1, ** P<.05, *** p<0.01

The results above imply that sanctions damage trade and market activity in the regional economy. The damage to the trade sector is obvious and direct since the sanctions prohibit importing and exporting certain commodities. The fact that the market's positive effect on the regional economy disappears under sanctions implies that the effect of sanctions is transmitted to the market sector. Accumulation of the impact of sanctions shrinks individuals' purchasing power and may cause a depression in the market activities.

The results are congruent with other evidence on the effect of sanctions. First, the immediate drop in North Korean trade supports the negative effect of trade hub proximity under the sanction regime. According to KOSIS, export decreased by 37.2% in 2017 and 86.3% in 2018. Import increased by 1.8% in 2017 but decreased by 31.2% in 2018. According to 장형수 & 김석진 (2019), the balance of payment of North Korea in 2018 is estimated to be −1–1.1 billion USD, while total foreign exchange reserves are estimated to be 3.5–4.5 billion USD in 2017. Although North Korea has found some detours for evading sanctions, it seems difficult to make up for a large trade deficit unless sanction measures are lifted. Since market and trade are mutually dependent on one another (임수호 et al., 2017), it seems reasonable that a drastic decrease in trade and foreign reserves would contract market activities.

Nevertheless, regions near wholesale markets appear to cope with sanctions better. This may be because domestic distribution chains gain relative importance as alternative sales routes to exports. Another possibility is that the connectivity to the wholesale market becomes more important in securing resources.[8] However, it is important to note that such effects are in relative terms compared to other regions. Even in regions where major wholesale markets are located, the net effect of sanctions is negative when considering the comprehensive effects on market size and trade.

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[8] The fact that food shortage in 2007–2009 was similar to "rural famine," compared to the period of the "Arduous March," which was an "urban famine" (홍민, 2016), demonstrates the importance of the interconnectivity of the distribution channel of resources upon the crisis.

The above results imply that the impacts of sanctions are highly dissimilar across regions, depending on the existing and accessible economic resources prior to the sanction period. Regions with high market activity and trade participation suffer more and those near domestic trade hubs cope relatively better with sanctions. Figure 2–7, 8, and 9 demonstrate this apparent phenomenon. Each of the figures presents the partial effects of every quartile increase in market size before sanctions, proximity to trade hubs before sanctions, and proximity to wholesale markets following the implementation of sanctions.

Figure 2–7 indicates that, when considering only the periods before sanctions, increase in market size from the 5th percentile to the 1st quartile, from the 1st quartile to the 2nd quartile, from the 2nd quartile to the 3rd quartile, and from the 3rd quartile to the 95th percentile increases regional SOL by 6.7%, 3.4%, 8.4%, and 9.6%, respectively. The partial effects are larger than the baseline results that consider both periods. Like two sides of a coin, the partial effects can be considered as damages related to sanctions through the channel of market activities because such effects are insignificant under sanctions. The result demonstrates that regions with relatively larger market sizes suffer more from sanctions.

Figure 2–8 presents the effect of the trade before sanctions. An increase in the proximity to trade hubs from the 5th percentile to the 1st quartile, from the 1st quartile to the 2nd quartile, from the 2nd quartile to the 3rd quartile, and from the 3rd quartile to the 95th percentile increases regional SOL by 3.1%, 1.6%, 2.5%, and 13.1%, respectively, before sanctions. Similar to the baseline results, the partial effect is much larger at the top quartile compared to other quartiles. It also implies that sanctions result in harsher damage to regions near ports or customs that have actively participated in trade.

Figure 2–9 presents the partial effect of the proximity to wholesale markets under sanctions. An increase in the proximity to the trade hubs from the 5th percentile to the 1st quartile, from the 1st quartile to the 2nd quartile, from the 2nd quartile to the 3rd quartile, and from the 3rd quartile to the 95th percentile increases regional SOL by 4.2%, 2.1%, 3%, and 9.3%, respectively under sanctions. This indicates that regions near the wholesale market have much higher SOL levels compared to other regions under the sanction regime. This may be because the domestic economy may become relatively more important under circumstances in which trade is prohibited than previously. However, it is notable that this effect is relative, not an absolute value.

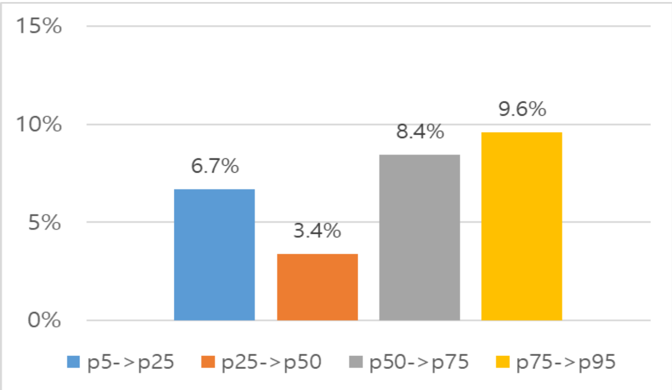

Figure 2-7. Partial Effects of Market Prior to Sanctions

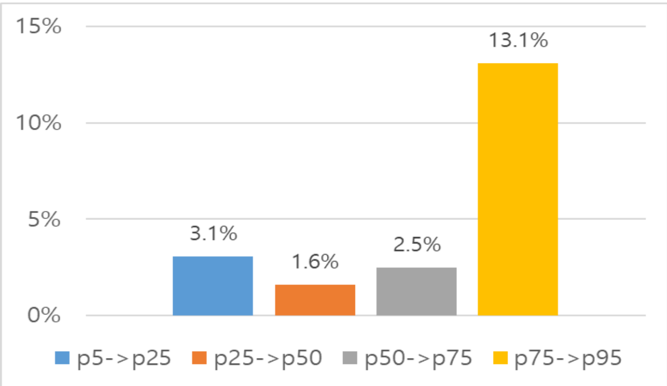

Figure 2-8. Partial Effects of Trade Hub Proximity Prior to Sanctions

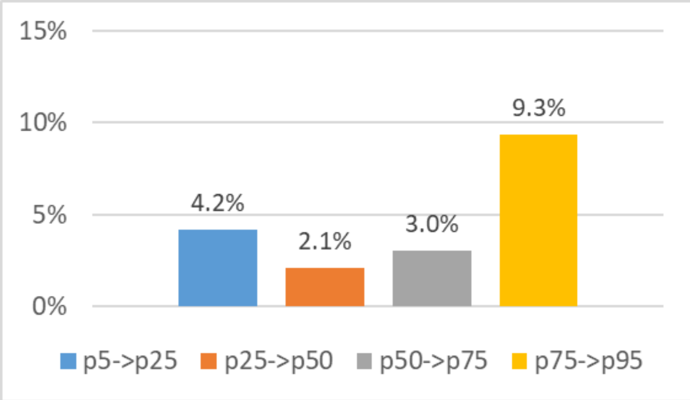

Figure 2-9. Partial Effects of Wholesale Market Proximity After Sanctions

3.4. Robustness Check

One of the concerns regarding the use of nighttime light for researching the North Korean economy is that the state monopolizes the electricity supply. The state determines how much electricity is distributed and to whom. According to 박은진 (2018), electricity is first supplied to the royal court economies, then to national strategic industrial complexes, important public facilities, and lastly, to general industrial production sites and households. Also, in terms of national development or construction projects, such sites will be bright even with no real electricity demand. For instance, in the case of Samjiyeon city, which Kim Jong-un has intensively developed since 2017 as part of the development of the tourism industry, SOL increased 351% in 2017 compared to the previous year.

Two measures assess whether the results are robust to state control over electricity usage. First, the annual media coverage of each county is included in the control variable to control for national strategic projects. Since the North Korean media is state-run, it actively promotes the state's business. For instance, the amount of media coverage in Samjiyeon city increased by 150% in 2017. Since data only since 2015 can be accessed, the regression is based on a subsample of 2015–2019 when the news coverage variable is included.

Second, lit area density, rather than luminosity, is used as a dependent variable. Special facilities, such as monuments, statues of Kim Jong-un, and other national importance sites, are likely always to be bright. Although the previous SOL level is controlled in the baseline regression model, the light intensity may not perfectly rule out lights in special facilities. Since nighttime light use is not universal in North Korea, marginal changes in light usage may more accurately represent real changes in people's electricity demand. Thus, lit area density, which measures the extensive margin, is used as an additional dependent variable.

The robustness check on the baseline results is presented in Table 2-9 and based on the Tobit model. Column (1) is identical to the baseline result in Table 2-3. Column (2) includes the news coverage variable, which has a significant positive coefficient, as expected, and the market size and trade hub proximity also have significant positive coefficients under control. Columns (3) and (4) use lit area density as dependent variables. Column (4) adds the sanction dummy and annual electricity supply instead of year fixed effects to evaluate the effect of sanctions. In both columns (3) and (4), market size and trade hub proximity have positive significant coefficients, although the coefficient of trade hub proximity is smaller in column (4). The sanction period dummy also has a significant negative coefficient. In all specifications, coefficients of variables other than market and trade hub proximity are insignificant.

Table 2-10 presents the average marginal effects. The marginal effect of market size is almost identical when lit area density is used instead of SOL. The marginal effect of market size increases when the news coverage variable is controlled for, as shown in column (2). For proximity to the trade hubs, the marginal effects are similar in all specifications. Finally, the effect of sanctions increases when lit area density is used instead of SOL, as shown in column (4). Sanctions decrease SOL by 5.3% each year, but lit area density decreases by 7.0% annually.

Table 2-9. Robustness Test for the Baseline Result

	(1) ln(SOL)	(2) ln(SOL)	(3) ln(Lit density)	(4) ln(Lit area density)
ln(Market)	0.167***	0.218***	0.147***	0.147***
	(0.059)	(0.073)	(0.051)	(0.052)
ln(Prox. wholesale)	0.080	0.082	0.063	0.082
	(0.082)	(0.107)	(0.071)	(0.070)
ln(Prox. trade)	0.137*	0.151*	0.119**	0.100*
	(0.070)	(0.091)	(0.060)	(0.060)
ln(Mining firms)	0.028	0.049	0.023	0.014
	(0.078)	(0.087)	(0.069)	(0.069)
ln(Light firms)	0.111	-0.061	0.101	0.106
	(0.098)	(0.124)	(0.085)	(0.087)
ln(Heavy firms)	-0.038	-0.138	-0.024	-0.013
	(0.098)	(0.104)	(0.086)	(0.088)
ln(News)		0.785***		
		(0.113)		
Sanction Dummy				-0.521***
				(0.153)
ln(Electric Supp.)				6.520***
				(1.124)
Observations	1239	885	1239	1239
R-squared				
sigma	2.045***	2.070***	1.830***	1.847***
	(0.126)	(0.137)	(0.115)	(0.117)

Note: Robust standard errors clustered for counties in the parentheses; * P<.1, ** P<.05, *** p<0.01

Table 2-10. Comparison of the Average Marginal Effects

	(1) ln(SOL)	(2) ln(SOL)	(3) ln(Lit density)	(4) ln(Lit area density)
ln(Market)	0.022***	0.032***	0.020***	0.020***
	(0.008)	(0.011)	(0.007)	(0.007)
ln(Prox. wholesale)	0.011	0.012	0.008	0.011
	(0.011)	(0.016)	(0.010)	(0.010)
ln(Prox. trade)	0.018**	0.022*	0.016**	0.013*
	(0.009)	(0.013)	(0.008)	(0.008)
ln(Mining firms)	0.004	0.007	0.003	0.002
	(0.010)	(0.013)	(0.009)	(0.009)
ln(Light firms)	0.015	-0.009	0.014	0.014
	(0.013)	(0.018)	(0.012)	(0.012)
ln(Heavy firms)	-0.005	-0.020	-0.003	-0.002
	(0.013)	(0.015)	(0.012)	(0.012)
Sanction Dummy				-0.070***
				(0.022)
Observations	1239	885	1239	1239

Note: Robust standard errors clustered for counties in the parentheses; * P<.1, ** P<.05, *** p<0.01

Table 2-11 presents the robustness test results for the sanction transmission channel. Column (1) is the result in column (6) of Table 2-7, column (2) adds a news coverage variable, and column (3) uses lit area density as a dependent variable instead of SOL. Table 2-12 presents the respective average marginal effects. The effect of market, proximity to trade hubs, and proximity to the wholesale markets on lit area density are similar to the effects on SOL.

The market has a positive effect before sanctions, and this effect decreases under sanctions, as does the effect of trade hub proximity. Proximity to the wholesale market is positive only in the sanction period. The average marginal effects in column (3) of Table 2-12 are similar to the result in column (1), except that the effect of trade hub proximity slightly decreases.

When the news coverage variable is added as in column (2), a few changes arise. First, the marginal effect of market size increases by 50%, from 0.028 to 0.042, before sanctions. Second, the average marginal effects of trade hub proximity before sanctions become insignificant. However, it appears to result from the fact that the effect of trade hub proximity is non-linear to the proximity. Figure 2-10 presents the marginal effect of trade hub proximity at each level before and following the implementation of sanctions for the result in column (2) of Table 2-11. The marginal effect of trade hub proximity is insignificant in low percentiles, whereas it is significantly over zero in upper percentiles before sanctions. The marginal effect is insignificant in all percentiles after sanctions. Thus, other than regions located far from trade hubs, the main result of the sanction channel through trade hubs persists, even when the news coverage variable is controlled for.

Third, the marginal effect of wholesale market proximity after sanctions is insignificant on average. As demonstrated in Figure 2-11, the marginal effect at each level of proximity to wholesale markets reveals that the relative advantage of the closeness to wholesale markets under sanctions is not universally significant but holds only in regions close to wholesale markets.

Lastly, heavy industry appears to have a negative coefficient prior to sanctions, and this effect disappears under sanctions. This suggests that when the state-sponsored effect on a few heavy industry complexes is ruled out, regions with more heavy industry have relatively lower SOL in normal periods. Under sanctions, the combination of increased domestic coal supply due to the prohibition of coal export and the state's need to construct self-reliant industrial linkage may have had an effect. However, with continuous restrictions on export and capital goods import, this effect may likely be time-limited.

Table 2-11. Robustness Test for the Sanction Transmission Channel

	(1) ln(SOL)	(2) ln(SOL)	(3) ln(Lit area density)
ln(Market)	0.222***	0.381***	0.195***
	(0.051)	(0.089)	(0.046)
ln(Market) X Sanction	-0.138	-0.273**	-0.123*
	(0.089)	(0.134)	(0.073)
ln(Prox. wholesale)	-0.046	-0.091	-0.046
	(0.097)	(0.136)	(0.086)
ln(Prox. wholesale) X Sanction	0.295**	0.289*	0.253**
	(0.123)	(0.148)	(0.110)
ln(Prox. trade)	0.225***	0.260**	0.176**
	(0.077)	(0.114)	(0.068)
ln(Prox. trade) X Sanction	-0.210**	-0.185	-0.137*
	(0.093)	(0.124)	(0.081)
ln(Mining firms)	0.043	0.063	0.025
	(0.088)	(0.123)	(0.083)
ln(Mining) X Sanction	-0.034	-0.024	-0.002
	(0.133)	(0.170)	(0.122)
ln(Light firms)	0.190	0.091	0.160
	(0.118)	(0.178)	(0.106)
ln(Light) X Sanction	-0.180	-0.241	-0.134
	(0.147)	(0.187)	(0.138)
ln(Heavy firms)	-0.140	-0.331**	-0.104
	(0.114)	(0.147)	(0.105)
ln(Heavy) X Sanction	0.235	0.320*	0.185
	(0.144)	(0.177)	(0.138)
ln(News)		0.770***	
		(0.112)	
Observations	1239	885	1239
R-squared			
sigma	2.040***	2.057***	1.826***
	(0.126)	(0.137)	(0.115)

Note: Robust standard errors clustered for counties in the parentheses; * P<.1, ** P<.05, *** p<0.01

Table 2-12. Average Marginal Effects by Sanction Regime: Lit Area Density

		(1) ln(SOL)	(2) ln(SOL)	(3) ln(Lit area density)
ln(Market)	Before	0.028***	0.042***	0.023***
		(0.008)	(0.013)	(0.007)
	After	0.011	0.018	0.010
		(0.013)	(0.018)	(0.012)
ln(Prox. wholesale)	Before	-0.005	-0.009	-0.004
		(0.012)	(0.015)	(0.010)
	After	0.040*	0.047	0.037**
		(0.022)	(0.029)	(0.019)
ln(Prox. trade)	Before	0.029**	0.028	0.021**
		(0.013)	(0.017)	(0.010)
	After	0.004	0.019	0.008
		(0.014)	(0.022)	(0.013)
ln(Mining firms)	Before	0.006	0.007	0.003
		(0.012)	(0.014)	(0.010)
	After	0.003	0.011	0.005
		(0.017)	(0.023)	(0.017)
ln(Light firms)	Before	0.024	0.011	0.019
		(0.016)	(0.020)	(0.014)
	After	-0.002	-0.035	0.001
		(0.018)	(0.026)	(0.018)
ln(Heavy firms)	Before	-0.017	-0.033*	-0.011
		(0.015)	(0.019)	(0.013)
	After	0.012	-0.006	0.011
		(0.019)	(0.024)	(0.019)
Observations		1239	885	1239

Note: Robust standard errors clustered for counties in the parentheses; * P<.1, ** P<.05, *** p<0.01

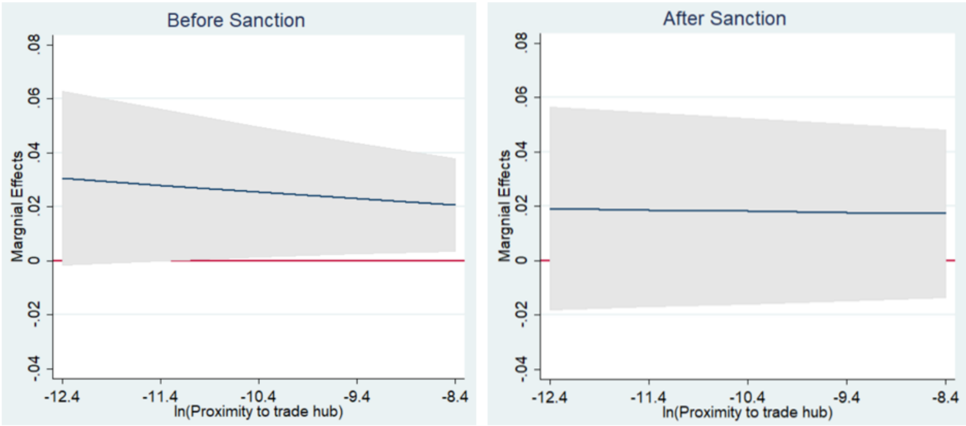

Figure 2-10. Marginal Effect of Proximity to the Trade Hubs

Note: The gray area represents a confidence interval at a 10% significance level and the red horizontal line represents zero.

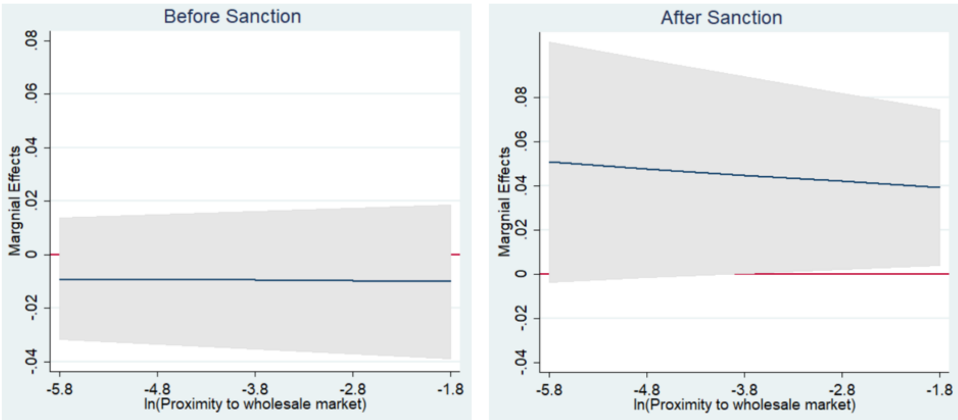

Figure 2-11. Marginal Effect of Proximity to the Wholesale Market

Note: The gray area represents a confidence interval at a 10% significance level and the red horizontal line represents zero.

Table 2-13 presents the regression results of the growth rate in SOL and lit area density before and after sanctions. Since the previous results include a lagged dependent variable while estimating the POLS or the cross-sectional Tobit model due to time-invariant variables, it suffers from endogeneity. Thus, a single period OLS analysis is implemented with growth rates during 2012–2016 and 2016–2019 as dependent variables representing before and after the sanction period. For the independent variables that have serial variation, average values of each sub-period are used. The OLS model is estimated since the dependent variable is growth rate and a censoring point cannot be identified. The results are similar to the main results. Market size and proximity to trade hubs have a positive effect on SOL and lit area density growth prior to sanctions and proximity to wholesale markets has a positive effect following sanctions. Industry variables are insignificant.

Table 2-13. Result of the Growth Rate of SOL and Lit Area Density

	(1) Before D4.ln(SOL)	(2) After D3.ln(SOL)	(3) Before D4.ln(Lit)	(4) After D3.ln(Lit)
L4.ln(SOL)	−0.316***			
	(0.069)			
L3.ln(SOL)		−0.320***		
		(0.083)		
L4.ln(Lit area density)			−0.319***	
			(0.069)	
L3.ln(Lit area density)				−0.326***
				(0.072)
ln(Market)	−0.128	2.494	−0.410	1.867
	(2.936)	(2.751)	(2.681)	(2.327)
ln(Proximity to wholesale market)	−1.708*	1.347*	−2.501**	1.960**
	(0.913)	(0.803)	(1.256)	(0.894)
ln(Proximity to trade hub)	0.708**	0.209	0.526*	0.179
	(0.324)	(0.361)	(0.297)	(0.283)
ln(Mining firms)	0.339	1.247	0.088	0.915
	(0.828)	(0.791)	(0.717)	(0.644)
ln(Light firms)	0.011	−0.896	0.267	−0.867
	(0.697)	(0.690)	(0.659)	(0.591)
ln(Heavy firms)	−0.491	−0.425	−0.547	−0.384
	(0.407)	(0.619)	(0.360)	(0.485)
Observations	177	177	177	177
R-squared	0.33	0.20	0.33	0.26

Note: Robust standard errors are in the parentheses; * P<.1, ** P<.05, *** p<0.01

4. Conclusions

This research analyzes the determinants of North Korean regional economic levels and the effects of sanctions using nighttime light as a proxy for regional economic status during the Kim Jong-un regime. The effect of market, trade, and formal industrial sectors are considered as the main possible contributing factors. The Tobit model is estimated to manage the censoring problem since 20%–30% of the counties display no observable light. To perform empirical analysis, a county-level database of various economic variables is constructed using geographical data, satellite data, North Korean media, and other considerations that have rarely been used in North Korean economic research.

The results of the study are threefold. First, market size and proximity to trade hubs are important determinants for regional economies. A quartile increase in market size increases regional SOL by 5.3% on average. The effect of proximity to trade hubs is non-linear. Regions over the 75th percentile in proximity to trade hubs have over 7.8% higher SOL than other regions, but the effect rapidly decreases as the distance to the trade hubs increases. The effects of formal industrial sectors are insignificant, suggesting that the contribution of the formal sector or official workplaces on household income may be insubstantial.

Second, the annual SOL of the regions decreases by 5.4% on average during the sanction period. The magnitude of the effect on SOL is similar to that associated with a quartile increase in market size, which is sizable. When the lit area density, which represents an extensive margin that excludes lights from special facilities, is used as a dependent variable instead of SOL, the impact of sanctions is intensified. The proportion of lit area pixels of each region decreases by 7.0% each year during the sanction period.

Finally, the effect of sanctions is highly divergent across regions, presenting severer impact on regions near trade hubs or with large markets. The positive effects of the market and the proximity to trade hubs are only significant prior to sanctions and its effect disappears under sanctions. Since the effects of market and trade are sizable before sanctions, the damage to areas that had appreciated the benefit of market and trade activity would be severe. Conversely, proximity to wholesale markets has a positive effect on regional economies under the sanction regime, implying that regions near domestic distribution hubs better cope with sanctions than other regions. This may be because domestic logistics gain relative importance as an alternative sales route, or as a distribution hub of economic resources under sanctions.

Chapter 3. The effect of trade on the North Korea Economy: Analysis of the Channel

1. Introduction

Many studies on the role of North Korean trade identify the positive effects of trade on the economic growth of North Korea (Jung, 2016; Jin, 2003; 김병연, 2011; Sato & Fukushige, 2011). However, when considering the trade policy adopted by the North Korean government, it is unnatural. North Korea traditionally pursued an extreme import substitution strategy, emphasizing that the national economy is self-sufficient. As 임수호 et al. (2017) discusses, with a purpose to secure political independence, the authority pursued an "Independent National Economic Construction Strategy" to secure inputs autonomously and achieve independent reproduction by linking domestic production and consumption. The role of trade was confined to obtaining insufficient or inferior commodities from within the nation. This differs from typical socialist countries that trade dominantly within the socialist bloc.

The composition of imported goods reflects such a trade strategy. A large proportion of imported goods are for heavy industry production that the North Korean government prioritized mainly for domestic purposes. Based on imports from China in 1995-2016,[9] 26% of the imported goods represented intermediate goods and raw materials for heavy industry. Assuming that most imported capital goods and fuels are used in the heavy industry, the share of imports for heavy industry production may account for up to 54% of North Korean imports.

However, international experience has demonstrated that the

[9] It is calculated by the author based on the data from the Korean International Trade Association (KITA).

import substitution strategy, mostly adopted in Latin American countries, has not been successful. It interrupts competition and efficient resource allocation, places a relative penalty on export sectors, and production activities cannot appreciate economies of scale without a sizable domestic economy (Baldwin, 2004). Even though the purpose of the import substitution strategy in North Korea differs from some of the associated Latin American countries, the nation adopted a similar trade policy of import substitution.

This research aims to fill the gap between the international experience and what research on the effect of North Korean trade has found by analyzing the channels through which trade affects the North Korean economy. Some studies have investigated the channels through which trade affects the North Korean economy based on the Granger causality test. Jung (2016) found that export to China and capital goods import from China Granger-caused North Korean growth in 1970-2012. Sato and Fukushige (2011) found that import Granger-caused North Korean GNP prior to, but not following, the collapse of the Soviet Union, . In contrast to previous studies that analyzed the channels of trade effect in a time series framework, this research assumes a regional panel data approach. Since regions' economic resources are heterogeneous, each regions' involvement in trade differs across regions in terms of the aspects, intensity, and method. Panel analysis at the county level allows the use of such diverse patterns and thus avails the analysis of the channels through which trade affects the North Korean economy.

For 2001-2016, the research examines the effect of three possible channels: export-led growth (ELG), import-led growth (ILG), and externality of trade. The discussion between export-led growth and import-led growth has been active. Export may cause growth through increased production, enhancement of resource allocation efficiency and productivity, and the benefit of economies of scale. Since mining and apparel processing industries led export growth in North Korea, the regions with advanced mining and light industries would have benefited from the export if the ELG channel was valid. Import may also induce growth, particularly through the transfer of technology embodied in imported goods. If the ILG channel was valid, capital and intermediate goods import would have benefited regions with developed heavy and mining industries that received priority in resource allocation by the state.

For North Korea, there is another unique possible channel in addition to ELG and ILG, which is the marketization channel. Research finds that rapid growth in trade of North Korea after the 2000s provided a chance for markets and informal sectors to expand (임수호 et al., 2017). The North Korean government enlarged the autonomy of trade companies as trade quantity and diversity expanded. New economic activities involved in trade were also generated, such as logistics, warehousing, and other related services. These changes may have contributed to the growth of markets and informal sectors in North Korea, generating positive externalities and benefiting the economy. Since various market policies were implemented during the research period, the effect of market policy is considered as an extension.

To examine the effect of channels, nighttime light ratio is used as a proxy for regional economic level and the combinations of trade series and regional features are used as main variables. The findings of the research are threefold. First, the ELG channel is valid only for the mining sector and not for light industry. Second, the ILG channel appears to be insignificant in the research period, which is rather surprising since the North Korean government put much effort into recovering the nation’s economy. Third, both export and import benefit regional economies through the marketization channel, regardless of the market policy regime.

The rest of this chapter is presented in three sections. In section 2, the hypothesis, regression model, and data are presented. The results and discussions are detailed in section 3, and section 4 concludes.

2. Method and Data

2.1. Hypothesis

There are three hypotheses to be tested in this research. The first hypothesis involves export-led growth. Export may cause growth through various routes, such as economies of scale, benefits from the international market competition, and other effects. For North Korea, export was traditionally a means of payment to import necessary products in the form of barter trade; however, after the late 2000s, exporting grew rapidly in North Korea. Increasing demand of China for mineral products, accompanied by a rapid increase in the international price of mineral products was the main cause of the growth of North Korean export. According to 김다울 et al. (2020), import caused minerals export before 2010, but this relationship reversed and minerals export caused imports after that. Thus, a possibility exists that export caused growth in North Korea, particularly after the late 2000s when mineral export grew rapidly.

If the channel is effective, the mining sector, and the light industry which led to export growth, would both benefit from it. In the channel of export-led growth, the volume of export in addition to the composition of export is important. Exporting goods that are associated with higher productivity causes higher growth (Hausmann et al., 2007). Due to the nature of the mining industry, which is characterized by relatively low productivity growth and technology development, if the effect is limited to the mining industry, the channel may be temporary or even detrimental in the long term if resources are continuously transferred to low-productivity sectors.

The second hypothesis entails import-led growth. According to the endogenous growth theory, import can cause growth since importing capital and intermediate goods of advanced technology may generate knowledge and technology transfer (Grossman & Helpman, 1991; Coe & Helpman, 1995). Since North Korea did not have the capability to produce advanced capital goods, it depended on imports from countries with more developed technologies. North Korea has traditionally emphasized four industries of electricity production, coal production, metal production, and train transportation, investing the nation's limited resources in those industries as top priorities. If the import-led growth channel is effective, the heavy and mining industry favored by the North Korean government would benefit from inputs import.

The third hypothesis regards the externality of trade; namely, the marketization channel. Research finds the reciprocal impact of markets and trade expand one another (임수호 외, 2017). The growth of trade causes decentralization and the increased autonomy of lower-level economic agents. This creates an institutional and environmental background for the development of the market. The market also fills the gap between the plan and reality. In reality, many of the production sites run by official trade companies are operated by private capitalists known as 'Don-ju'(조한범 et al. 2016). The import of consumption goods also encourages the growth of the market and contributes to growth in the service industry.

The validity of the marketization channel may be affected by the policy environment of the state. The policies of the North Korean government went through a series of changes during the research period.[10] In 2002, North Korean policy implemented a 7.1. Measure that rationalized the national price system and enlarged companies' autonomy. Evaluation criteria changed from the

[10] The explanation of the evolving market policies of North Korea is based on Chapter 3 of 홍민 et al. (2018).

achievement of the plan to a sort of revenue index, in which firms were allowed to sell surplus products to the markets and were obliged to pay employees' wages with their own resources. Production factor markets between firms were also introduced. The North Korean government established the first official market in the following year.

The North Korean government's attitude changed and it started to repress the markets in 2005 through strengthening market monitoring, restricting products and places for sales, and other oppressive tactics. In 2009, the North Korean government attempted to shut down the official markets and absorbed citizens' cash reserves through currency reform. However, markets had already become deeply rooted into everyday North Korean economic activities and substantial side-effects of currency reform, such as hyper-inflation and shortages arose. The North Korean government eventually withdrew a series of repressive policies regarding the market in 2010.

In 2013, Kim Jong-un implemented a new economic reform called the "Socialist Corporate Responsibility Management System," strengthening the autonomy of companies on the production plan, pricing, and financial management, and other related concerns, and allowing the sale of final goods to market. This research analyzes whether the validity of the marketization channel varies according to evolving market policy.

2.2. Regression model

The regression model of the research is inspired by Lee (2018) that analyzed North Korea's response strategy to sanctions based on the interaction term of annual sanction index and region-specific characteristics. The channels through which trade affects the economy are examined using the regional variation in the distribution of industries and markets. The economic level is evaluated by the SOL proportion of each county. The regression equation is in (1). y_{it} is the SOL ratio of county i in year t, $Trade_t$ is the annual total export, total import, and inputs import divided by the export unit value and import Unit value of North Korea. Trade variables only have serial variations and are unitary across the regions. $Hypo_i$ includes the number of heavy, mining, and light industries and the number of market vendors. Z_{it} includes control variables and county fixed effect η_i and year fixed effect θ_t are included.

$$y_{it} = \beta_0 + \beta_1(Trade_t \times Hypo_i) + \beta_2 Z_{it} + \eta_i + \theta_t + \varepsilon_{it} \tag{1}$$

The hypotheses are tested by the coefficient β_1 and the following will hold if each of the hypothesis is true.

Hypothesis 1. Export-led Growth

- $\beta_1 > 0$ for the mining and light industries with total export series

Hypothesis 2. Import Led Growth

- $\beta_1 > 0$ for the heavy and mining industries with inputs import series

Hypothesis 3. Marketization Channel

- $1 > 0$ for the market size with total export and import series

Upon estimating the equation (1), there's a methodological problem due to the data limitation. Market variable may suffer from endogeneity problem. It measures the number of market vendors in 2016 which may be affected by the past regional economic performance. Thus, 2SLS fixed effect model is estimated with IVs. The number of markets and the number of train stations in the Japanese colonial era are used as IVs for the market variable.

To evaluate the effect of market policy on the marketization channel, equation (2) is estimated. The policy variable is constructed as in Table 3-1. Since some studies find that repressive market policy in 2005-2009 is ineffective(양문수, 2012), four versions of specifications are introduced. Uniform Effect assumes that the magnitude of the marketization channel effect is uniform regardless of the market policy regime. Continuous expansion assumes that the market continuously expands even in the period of the repressive market policy. Gradual expansion assumes that the market maintains the status quo during the repressive market policy period and expands afterward. Temporary regression assumes that the market regresses temporarily during the anti-market policy period and expands afterward. Lastly, the pro-market dummy specification simply discriminates between pro-market and anti-market policy periods.

$$y_{it} = \beta_0 + \beta_1(Trade_t \times Region_i) + \beta_2(Trade_t \times Region_i \times Policy_t) \qquad (2)$$
$$+\beta_3 Z_{it} + \eta_i + \theta_t + \varepsilon_{it}$$

Table 3-1. Specification of the Market Policy Variable

	Uniform Effect	Continuous expansion	Gradual expansion	Temporary regression	Pro-market Dummy
2001	1	0	0	0	0
2002-2004 (7.1 Measure)	1	1	1	1	1
2005-2009 (Repressive Policy)	1	2	1	0	0
2010-2012 (Normalization)	1	3	2	1	1
2013-2016 (Socialist Corporate Responsibility Management)	1	4	3	2	1

2.3. Data

The research uses the nighttime light data in 2000-2016 as a proxy for the economic level. Among the two sets of the nighttime light data, the DMSP-OLS dataset is provided for 1992-2013 and the NPP-VIIRS dataset is provided from 2012 until the present. It is well known that the quality of the NPP-VIIRS data is superior to DMSP-OLS data in terms of serial consistency, sensitivity, accuracy, and saturation (Bennett and Smith, 2017). Thus, the research uses DMSP-OLS data for 2000-2011 and NPP-VIIRS data for 2012-2016.

There is a serial inconsistency problem in the sum of light(SOL) level. The DMSP-OLS data is observed by six different satellites and even within the same satellite, the quality of the observation degrades as time passes. Figure 3-1 shows the annual SOL level and the number of lit pixels observed by each satellite. Every satellite shows a decrease in the SOL and the number of lit pixels as the service life increases. Also, in 2010 when the satellite F18 starts observation, the SOL level and the number of lit pixel jumps. The serial inconsistency problem becomes even critical when connecting DMSP-OSL and VIIRS-NPP data with different observation schemes.

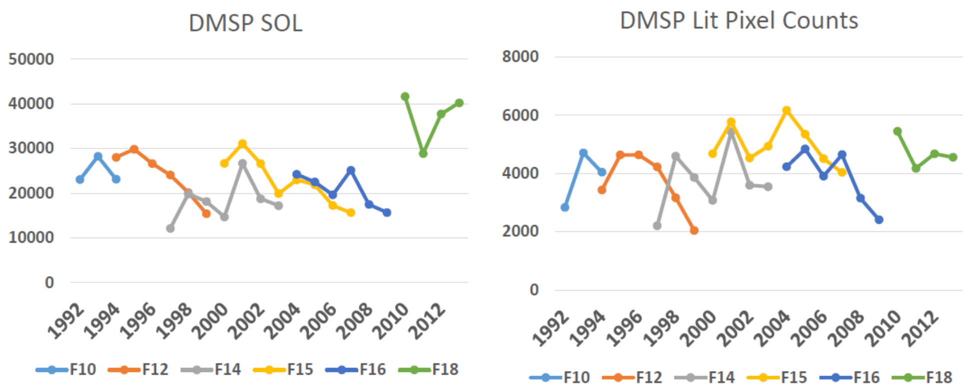

Figure 3-1. Serial Inconsistency of the OLS-DMSP Data

This research deals with this problem by transforming the nighttime light into the proportion variable. Even though the SOL level suffers from serial inconsistency, the proportion of each counties' SOL may be relatively consistent. Because cross-sectional variations are credible within each year despite the aforementioned features, this research detours the serial inconsistency problem by using the SOL proportion variables. Figure 3-2 shows the trend of the logged value of SOL and SOL proportion of capital or metropolitan cities of North Korea. In SOL level, a jump is observed in 2010 when the satellite is changed from F16 to F18, and a drop is observed in 2012 when the data are changed to NPP-VIIRS data. When the data is transformed to the proportion variable, such a tendency disappears.

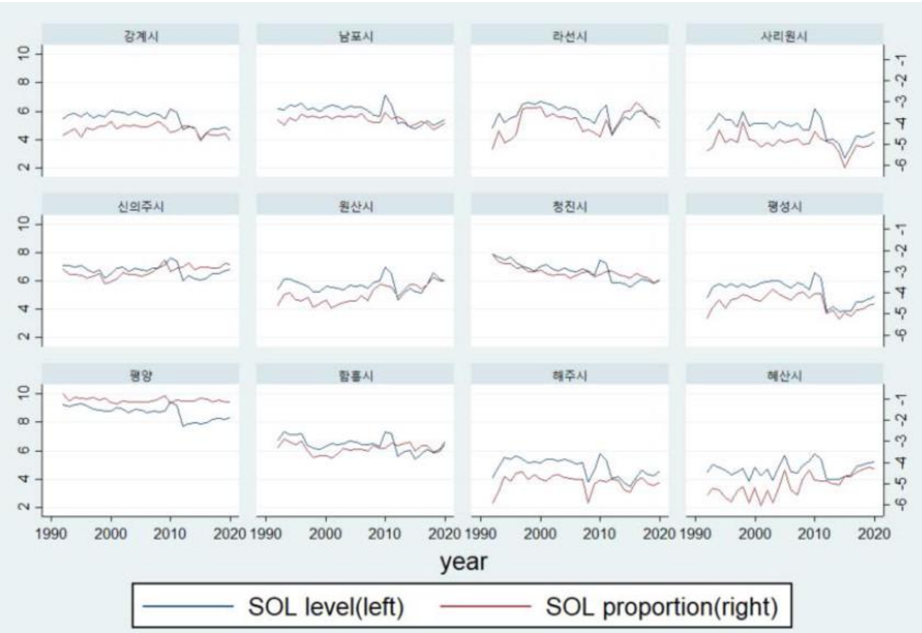

Figure 3-2. Trend of SOL Level and SOL Ratio in Major Cities

Source: 1992-2011 uses DMSP-OLS data and 2012-2019 uses NPP-VIIRS data.
Note: All are in logged terms

However, there may be a concern in directly connecting the DMSP-OLS nighttime light and NPP-VIIRS nighttime light data since the two datasets are generated under the different observation schemes. DMSP−OLS data is observed at 8:30−9:30 PM while the NPP−VIIRS data is observed at 1:30 AM. Observability of the dim lights and the spread phenomenon of lights are greatly improved in NPP−VIIRS data and the upper limit doesn't exist, while in DMSP−OLS the observed range is restricted to 0−63.

To test whether the data from two different datasets are connectable, a t−test is performed using the overlapping period of 2012−2013. As Table 3−2 shows, when the data is converted to the proportion variable, there is no statistical difference between OLS−DMSP data and NPP−VIIRS data, while for the SOL level variable, the data from OLS−DMSP show a higher level than NPP−VIIRS data. Thus, the transformation of SOL level to SOL proportions can solve most of the serial inconsistency problems.

Table 3−2. T−test on the Difference between DMSP and VIIRS

	Difference	SE	t-stat	p-value
ln(SOL level)	1.72	0.10	17	0.00
ln(SOL Proportion)	0.07	0.10	0.71	0.48

Note: The tested periods are 2012 and 2013 when the two data overlap.

Table 3−3 shows a list of variables that are used in the research, their description, and the sources. For trade, commercial trade with South Korea is included as well as with the rest of the world.[11] Total export to and import from the world except for South Korea are from KOTRA since UN Comtrade trade data contains many errors(이석 et al., 2010). For inputs import, UN Comtrade data is used since it allows categorization by the end−use. Inputs import includes capital goods (41, 51, 521 of BEC) and intermediate goods (111, 121, 2, 42, 53) imports of the Broad Economic

[11] Among inter−Korea trade, transactions for Kaesung Industrial Complex and Mt. Guemgang Tourism Project are likely to have impact only within the project area. Thus, corresponding trade values are added only to the project areas.

Category(BEC) code.

Inter-Korean trade is from the Ministry of Unification and only commercial trades are included. Inputs import from South Korea are downloaded in HS code and converted to BEC code using UN Comtrade's conversion table. Trade series are divided by export unit value and import unit value of the North Korea estimated by UNCTAD to be transformed to the real values. Also, the exclusion of crude oil imports since 2014 and the error in rice import from Japan in 2001 have been corrected.[12] The trade series are presented in Figure 3-3.

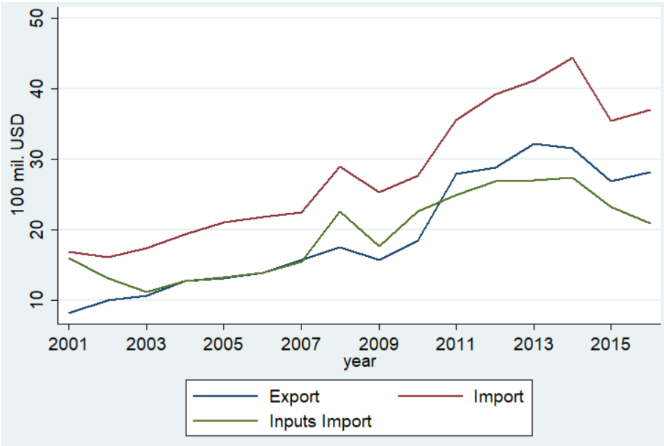

Figure 3-3. Trend of Export, Import, and Inputs Import

Source: Total trade with world is from KOTRA, inputs import from world from UN Comtrade, and trade with South Korea is from the Ministry of Unification.
Note: 1) For trade with South Korea, transaction for Kaesung Industrial Complex and Mt. Guemgang Tourism Project are excluded.
2) Rice import from Japan and crude oil from China are adjusted following 김석진(2007) and KOTRA, respectively.

Market size is measured by the number of market vendors reported in 홍민 et al. (2016). The number of markets and the

[12] KOTRA presumes that crude oil import from China is omitted in the UN data since 2014 and provide import value estimates based on the international price. Also, 김석진 외(2007) mentions that there is an error in the rice import from Japan due to erroneous valuation. This has also been corrected for.

number of train stations in the Japanese colonial era are obtained from the Korea Modern Electronic History Map and used as IVs for the market size of each county. The original map data are presented in Figure A−1 and Figure A−2. For the industry variables, three versions of variables are constructed. The first version is the number of mining, light industry, and heavy industry firms mentioned in Rodong newspaper during 2001−2016. The second is the weighted version that adds the number of news reports each year to the above 2001−2016 stock variables. This reflects annual production status better than the first version.[13] Since the first two versions are based on the stock of firms reported in the North Korean media during 2001−2016, it suffers from the endogeneity problem. Thus, the last version is the number of industrial complexes (composite enterprises) of each sector registered in 『Joseon Geographical Encyclopedia (조선지리전서)』.[14] Since the document was published in 1984 and includes the major big−scale enterprises and most of important industrial facilities were built before the 1990s, it may well reflect the current industrial distribution while evading the endogeneity issue.

The control variables include population and precipitation. In addition to this, the interaction terms between trade series and capital cities dummy, and between trade and transport cost are used to control for the differential effect according to the accessibility to trade sites. Transport cost is measured as the distance to the closest trade hubs. Since the fixed effect model is estimated, other region−specific effects are controlled for. The summary statistics are presented in Table 3−4. All variables except for the capital dummy are transformed to log. For market and industry variables, 1 is added before taking a log to avoid data loss.

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[13] Data on Rodong Newspaper are provided by the Korea Institute for Industrial Economics and Trade(KIET).

[14] The data is provided by 류학수 at the Obirin University, Japan.

Table 3-3. List of Variables

Variable	Description	Source
SOL proportion	Each county's SOL level divided by the total annual SOL level	2001-2011: DMSP 2012-2016: VIIRS
Total trade	Export and Import in 1990-2016 with world	KOTRA, Ministry of Unification
Inputs Import	Sum of the following categories of BEC: (Capital goods) 41, 51, 521 (Intermediate goods) 111, 121, 2, 42, 53	UN Comtrade, Ministry of Unification
Price Index	Export unit value, Import unit value	UNCTAD
Market	The number of market vendors in 2016	홍민 et al.(2016)
Industry	The number of firms mentioned in North Korean official media during 2001-2016 for light, mining and heavy industries (The number of annual news reports are added for the weighted industry variables.) The number of composite enterprises in 1984 by sector(light, heavy, mining)	Rodong Newspaper (2001-2016) 조선지리전서 (1984)
Population	Population aggregated from population by 1km²	World gridded population
Transport Cost	The closest distance to trade hubs	Calculated by the author
Capital cities	Provincial capitals, Nampo city, Rasun city	-
Precipitation	The level of precipitation	KOSIS
Colonial Market	The number of markets in the Japanese colonial era	한국근대전자역사지도
Colonial Stations	The number of stations in the Japanese colonial era	

Note: Data for the Rodong newspaper are provided by KIET and data for 조선지리전서 is provided by 류학수 at the Obirin University, Japan.

Table 3-4. Summary Statistics

	Obs	Mean	Std. Dev.	Min	Max
ln(SOL ratio)	1,614	-6.09	1.66	-11.67	-0.85
ln(Market)	1,614	9.08	2.06	0	14.92
ln(Light: F)	1,614	1.32	0.95	0	5.02
ln(Heavy: F)	1,614	1.24	1.04	0	4.87
ln(Mining: F)	1,614	0.67	0.67	0	2.20
ln(Light: W)	1,614	1.51	1.13	0	6.15
ln(Heavy: W)	1,614	1.50	1.31	0	5.74
ln(Mining: W)	1,614	1.02	1.16	0	4.84
ln(Light: IV)	1,614	0.29	0.55	0	3.14
ln(Heavy: IV)	1,614	0.29	0.55	0	3.26
ln(Mining: IV)	1,614	0.28	0.55	0	2.40
ln(Population)	1,614	11.74	0.72	9.59	14.74
ln(Dist. to trade hubs)	1,614	10.80	1.56	0	12.67
Capital cities	1,614	0.11	0.31	0	1
ln(Precipitation)	1,614	6.81	0.36	5.78	7.70
ln(Colonial Market)	1,614	1.28	0.52	0	2.89
ln(Colonial Station)	1,614	1.09	0.78	0	2.77

Note: 1 is added to market, industry variables and their IVs before taking logs.

3. Results

3.1. Export-Led Growth

Table 3-5 presents the result for the export-led growth hypothesis. Column (1) uses the number of firms reported in the Rodong newspaper during 2001-2016 as industry variables and column (2) uses the same firms' stock weighted by the annual news report. As those are based on a firm stock variable, which includes the future news report, they suffer from endogeneity. Column (3) and (4) rules out the endogeneity problem by using the number of firms reported in the North Korean official document in 1984. Column (4) additionally controls for the externality of the marketization channel through a 2SLS fixed effect model. For the market variable, the number of markets and stations in the Japanese colonial era are used as IVs. A test of overidentifying restrictions confirms the exogeneity of the IVs. The first stage result is presented in column (1) of Table A−1 in the Appendix and both IVs have positive significant coefficients.

For all versions of industry variables, an interaction term between export and the mining sector is significant, even when the externality of marketization is considered, validating that the export−led growth channel through the mining sector drives export growth. The result is identical when mineral export is used in place of the total export, as shown in Table A−2 in the Appendix.

Light industry, another possible beneficiary of ELG, is significant only when weighted industry variables are used in the FE model. The result seems to lack robustness since the unweighted version of industry variables in (1) or endogeneity−free industry variables in column (3) produce insignificant estimates. Moreover, the result using apparel exports instead of the total export in Table A−3 of the Appendix, which estimates the ELG hypothesis through the apparel exports more accurately by using the apparel export instead of total export and using the number of the apparel processing firms instead of the number of total light industry firms, casts additional doubts. As shown in the column (4) of Table A−3, an interaction term between apparel export and textile processing firms is insignificant. Thus, the growth channel through the apparel processing export appear to lack robustness. It implies that the ELG channel through the mining sector is dominant and it can be suggested that the ELG channel in North Korea mainly represents resource−led growth.

Table 3-5. Result for the Export-Led Growth

	(1) FE	(2) FE	(3) FE	(4) 2SLSFE
ln(Light: F) x ln(Export)	-0.315			
	(0.248)			
ln(Mining: F) x ln(Export)	0.835***			
	(0.283)			
ln(Heavy: F) x ln(Export)	0.414			
	(0.257)			
ln(Light: W) x ln(Export)		0.015*		
		(0.008)		
ln(Mining: W) x ln(Export)		0.012**		
		(0.005)		
ln(Heavy: W) x ln(Export)		0.007		
		(0.008)		
ln(Light: C) x ln(Export)			0.332	-0.247
			(0.282)	(0.432)
ln(Mining: C) x ln(Export)			1.080***	0.600*
			(0.273)	(0.358)
ln(Heavy: C) x ln(Export)			0.213	-0.338
			(0.292)	(0.407)
ln(Population)	1.930	0.237	2.341	4.448*
	(1.880)	(1.900)	(1.962)	(2.385)
ln(Precipitation)	0.393**	0.431**	0.396**	0.451***
	(0.160)	(0.167)	(0.161)	(0.164)
ln(Dist. trade) x ln(Export)	-0.266***	-0.247***	-0.252***	-0.487***
	(0.078)	(0.094)	(0.083)	(0.148)
Capitals X ln(Export)	-0.181	-0.074	-0.258	-1.494**
	(0.469)	(0.278)	(0.339)	(0.725)
Ln(Market) x ln(Export)				0.594**
				(0.296)
Constant	-36.531	-12.502	-38.338*	-65.334**
	(22.381)	(22.179)	(23.079)	(28.530)
Observations	1614	1614	1614	1614
R-squared	0.09	0.05	0.08	
IV Exogeneity Test Stat.				0.430
County FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Note: Robust standard errors clustered for counties in the parentheses; * P<.1, ** P<.05, *** p<0.01.

3.2. Import–Led Growth

Table 3–6 presents the result for the import–led growth hypothesis. Columns (1)–(3) are the results with unweighted industry variables, weighted industry variables, and endogeneity–free industry variables, respectively. Column (4) is the result of the 2SLS fixed effect model using market IVs. An overidentification restriction test confirms that the IVs are exogenous and the first stage result is presented in column (4) of Table A–1 in the Appendix, which reveals positive and significant coefficients for markets and stations in the Japanese colonial era. The interaction terms between inputs import and industry variables show insignificant results, except for the weighted version in column (2). This implies that the ILG channel through mining and heavy industries is not valid in North Korea. This result contradicts that of Jung (2016), who concludes that capital goods import from China Granger–caused the growth rate of North Korea in 1970–2012. It is likely that the difference arises from the difference in the research period. While Jung's (2016) research period includes the period before the Arduous March, when the rationing system was in operation, this research investigates the period following this time, when official rationing system is said to have been nullified. According to 이석기 et al. (2010), the official North Korean sector in the 2000s only partially recovered from the crisis and was unable to restore most of the industrial linkage structures despite the efforts of the state. The findings of this research, which indicate that the effect of factor imports on regional economies are invalid through any industries, is in congruence with the findings of 이석기 et al. (2010).

Table 3-6. Result for the Import-Led Growth

	(1) FE	(2) FE	(3) FE	(4) 2SLSFE
ln(Light: F) x ln(Inputs Import)	0.047			
	(0.249)			
ln(Mining: F) x ln(Inputs Import)	-0.143			
	(0.276)			
ln(Heavy: F) x ln(Inputs Import)	0.115			
	(0.266)			
ln(Light: W) x ln(Inputs Import)		0.013*		
		(0.008)		
ln(Mining: W) x ln(Inputs Import)		0.009*		
		(0.005)		
ln(Heavy: W) x ln(Inputs Import)		0.005		
		(0.008)		
ln(Light: C) x ln(Inputs Import)			0.131	0.026
			(0.304)	(0.385)
ln(Mining: C) x ln(Inputs Import)			-0.107	-0.205
			(0.312)	(0.335)
ln(Heavy: C) x ln(Inputs Import)			-0.042	-0.152
			(0.271)	(0.343)
ln(Population)	-0.584	-0.310	-0.564	-0.555
	(1.950)	(1.913)	(1.953)	(1.946)
ln(Precipitation)	0.436**	0.420**	0.431**	0.439**
	(0.171)	(0.169)	(0.170)	(0.171)
ln(Dist. trade) x ln(Inputs Import)	-0.059	-0.063	-0.058	-0.101
	(0.076)	(0.078)	(0.077)	(0.112)
Capitals X ln(Inputs Import)	-0.869**	-0.573**	-0.654**	-0.875*
	(0.408)	(0.247)	(0.294)	(0.524)
Ln(Market) x ln(Inputs Import)				0.110
				(0.226)
Constant	-1.590	-4.394	-1.244	-1.814
	(22.392)	(22.294)	(22.687)	(22.356)
Observations	1614	1614	1614	1614
R-squared	0.03	0.03	0.03	
IV Exogeneity Test Stat.				0.187
County FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Note: Robust standard errors clustered for counties in the parentheses; * P<.1, ** P<.05, *** p<0.01.

3.3. Marketization Channel

Table 3-7 presents the result for the marketization channel induced by export, and Table 3-8 shows the effect induced by import. Columns (1) and (2) of each table are the results for the fixed effect and 2SLS fixed effect model when only the marketization channel is considered. Columns (3)-(5) of each table are the results when trade effects through industrial production are controlled for. Except for column (1), the number of markets and stations in the Japanese colonial era are used as IVs for the market variable. Overidentifying restrictions test confirms the exogeneity of the IVs, which have significantly positive coefficients in the first stage, as shown in Table A-1 of the Appendix.

In Table 3-7, column (1) shows that an interaction term between export and market is significant, which implies that regions with large market benefit more from export. The coefficient becomes greater when market endogeneity is controlled for by the use of IVs in column (2). The result is similar under the control of the industrial production with weighted and endogeneity-free industry variables. Table 3-8 shows that an interaction term between imports and markets is significant in all specifications. The magnitude of the coefficient is greater than that of the interaction term with export in Table 3-7.

The results imply the complementary roles of market and trade that contribute to regional economies. It is the positive externality that the previous literature on North Korean trade has paid little attention to. Although unintended, trade fosters market activities by creating new economic opportunities and enhancing the autonomy of the low-level economic agents. Market activities, or informal activities in a broad sense, also cause growth of trade by improving resource allocation efficiency, allowing private investment, and increasing the demand for imports. Such reciprocal interaction between trade and markets results in regional economic growth.

Table 3-7. Result for the Marketization Channel with Export

	(1)	(2)	(3)	(4)	(5)
	FE	2SLSFE	2SLSFE	2SLSFE	2SLSFE
ln(Market) x ln(Export)	0.288***	0.547***	0.574	0.544***	0.594**
	(0.099)	(0.203)	(0.428)	(0.202)	(0.296)
ln(Population)	1.785	3.559	4.244	3.832	4.447*
	(2.096)	(2.405)	(2.585)	(2.354)	(2.384)
ln(Precipitation)	0.467***	0.485***	0.422***	0.474***	0.451***
	(0.166)	(0.169)	(0.160)	(0.168)	(0.164)
ln(Dist. trade) x ln(Export)	-0.357***	-0.460***	-0.453***	-0.462***	-0.487***
	(0.080)	(0.119)	(0.161)	(0.119)	(0.148)
Capitals X ln(Export)	-0.933**	-1.797**	-1.086	-1.858**	-1.494**
	(0.414)	(0.767)	(0.807)	(0.767)	(0.725)
ln(Light:F) x ln(Export)			-0.541		
			(0.331)		
ln(Mining:F) x ln(Export)			0.445		
			(0.393)		
ln(Heavy:F) x ln(Export)			0.055		
			(0.393)		
ln(Light:W) x ln(Export)				0.011	
				(0.009)	
ln(Mining:W) x ln(Export)				0.008	
				(0.005)	
ln(Heavy:W) x ln(Export)				0.005	
				(0.008)	
ln(Light:C) x ln(Export)					-0.247
					(0.432)
ln(Mining:C) x ln(Export)					0.601*
					(0.358)
ln(Heavy:C) x ln(Export)					-0.338
					(0.407)
Constant	-32.376	-54.616*	-61.664**	-57.687**	-65.485**
	(24.802)	(28.754)	(30.149)	(28.188)	(28.566)
Observations	1614	1614	1614	1614	1614
R-squared	0.06				
IV Exogeneity Test Stat.		0.643	1.507	0.814	0.43
County FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors clustered for counties in the parentheses; * P<.1, ** P<.05, *** p<0.01

Table 3-8. Result for the Marketization Channel with Import

	(1) FE	(2) 2SLSFE	(3) 2SLSFE	(4) 2SLSFE	(5) 2SLSFE
ln(Market) x ln(Import)	0.523***	0.950***	1.233*	0.925***	1.116**
	(0.166)	(0.332)	(0.674)	(0.337)	(0.462)
ln(Population)	0.193	0.704	0.957	0.948	0.914
	(1.922)	(1.932)	(1.986)	(1.912)	(1.930)
ln(Precipitation)	0.504***	0.555***	0.530***	0.538***	0.552***
	(0.169)	(0.169)	(0.163)	(0.169)	(0.167)
ln(Dist. trade) x ln(Import)	-0.565***	-0.729***	-0.790***	-0.727***	-0.809***
	(0.142)	(0.192)	(0.275)	(0.193)	(0.239)
Capitals X ln(Import)	-2.190***	-3.568***	-2.642*	-3.512***	-3.192**
	(0.746)	(1.323)	(1.362)	(1.340)	(1.296)
ln(Light:F) x ln(Import)			-0.943*		
			(0.562)		
ln(Mining:F) x ln(Import)			0.266		
			(0.639)		
ln(Heavy:F) x ln(Import)			-0.169		
			(0.707)		
ln(Light:W) x ln(Import)				0.013	
				(0.008)	
ln(Mining:W) x ln(Import)				0.006	
				(0.005)	
ln(Heavy:W) x ln(Import)				0.006	
				(0.008)	
ln(Light:C) x ln(Import)					-0.476
					(0.713)
ln(Mining:C) x ln(Import)					0.450
					(0.671)
ln(Heavy:C) x ln(Import)					-0.791
					(0.702)
Constant	-15.232	-24.152	-24.600	-26.815	-27.587
	(22.647)	(23.048)	(23.134)	(22.856)	(22.960)
Observations	1614	1614	1614	1614	1614
R-squared	0.05				
IV Exogeneity Test Stat.		0.144	0.432	0.283	0.073
County FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors clustered for counties in the parentheses; * P<.1, ** P<.05, *** p<0.01.

Because the growth of the market may be affected by trade as well as the institutional environment and government's attitude regarding the market, Table 3−9 and Table 3−10 further analyze the effect of the marketization channel under various market policy specifications. As the effectiveness of market policy itself has not been established through empirical research, four specifications are investigated. MK1 represents a continuous market expansion specification, MK2 represents a gradual market expansion specification, MK3 represents a temporary regression specification, and MK4 represents pro−market policy dummy specification.

Columns (1) and (2) in Table 3−9 and Table 3−10 assume that marketization channel effects are uniform regardless of the market policy regime and are identical to columns (1) and (2) of Table 3−7 and Table 3−8, respectively. The interaction terms between export and market in Table 3−9 are significant for all market policy specifications, and the market policy term is insignificant in all specifications; thus, the marketization channel effect involved with export is uniform across market policies. In other words, neither the pro−market policy nor anti−market policy affects the results of export on regional economies through the market.

The effect of market policy is slightly different for the marketization channel effect involved with import shown in Table 3−10. Interaction terms with dummy specification for the pro−market policy period in columns (9) and (10) are insignificant, whereas interaction terms with market policy variables of continuous or gradual market expansion scenarios in columns (3)–(6) are significantly positive for both the fixed effect and 2SLS fixed effect models. For temporary regression specification, only the 2SLS fixed effect model result is significant. The difference between the pro−market dummy and the other specifications is the expansion of the market during pro−market policy periods. Thus, it can be concluded that the effect of import on regional economies through market growth is enhanced by the pro−market policy.

Table 3-9. The Result for the Effect of Market Policy: Export

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Uniform Effect		Continuous Expansion		Gradual Expansion		Temporary Contraction		Pro-market dummy	
	FE	2SLSFE	FE	2SLSFE	FE	2SLSFE	FE	2SLSFE	FE	2SLSFE
ln(Market) x ln(Export)	0.288***	0.547***	0.411***	0.660**	0.571***	0.768**	0.366**	0.590**	0.309***	0.614***
	(0.099)	(0.203)	(0.154)	(0.288)	(0.213)	(0.378)	(0.148)	(0.265)	(0.113)	(0.222)
ln(Market) x ln(Export) x MKP1			-0.002	-0.002						
			(0.002)	(0.003)						
ln(Market) x ln(Export) x MKP2					-0.005*	-0.004				
					(0.003)	(0.005)				
ln(Market) x ln(Export) x MKP3							-0.002	-0.001		
							(0.002)	(0.003)		
ln(Market) x ln(Export) x MKP4									-0.001	-0.003
									(0.002)	(0.003)
ln(Population)	1.785	3.560	1.614	3.387	1.594	3.366	1.802	3.560	1.797	3.589
	(2.096)	(2.405)	(2.142)	(2.461)	(2.118)	(2.421)	(2.105)	(2.410)	(2.102)	(2.415)
ln(Precipitation)	0.467***	0.485***	0.478***	0.496***	0.473***	0.490***	0.460***	0.481***	0.465***	0.482***
	(0.166)	(0.169)	(0.166)	(0.168)	(0.166)	(0.169)	(0.166)	(0.169)	(0.166)	(0.169)
ln(Dist. trade) x ln(Export)	-0.357***	-0.460***	-0.338***	-0.441**	-0.357*	-0.450*	-0.377***	-0.477***	-0.388***	-0.508***
	(0.080)	(0.119)	(0.127)	(0.176)	(0.184)	(0.242)	(0.129)	(0.167)	(0.094)	(0.133)
Capitals X ln(Export)	-0.933**	-1.797**	-1.639**	-2.439**	-1.944**	-2.572*	-0.833	-1.597	-0.998**	-2.020**
	(0.414)	(0.767)	(0.699)	(1.108)	(0.960)	(1.419)	(0.652)	(0.989)	(0.492)	(0.850)
ln(Dist. trade) x ln(Export) x MKP1			-0.000	-0.000						
			(0.001)	(0.002)						

Capitals X ln(Export) x MKP1			0.010	0.009						
			(0.008)	(0.011)						
ln(Dist. trade) x ln(Export) x MKP2					-0.000	-0.000				
					(0.003)	(0.003)				
Capitals X ln(Export) x MKP2					0.018	0.014				
					(0.013)	(0.019)				
ln(Dist. trade) x ln(Export) x MKP3							0.000	0.000		
							(0.002)	(0.002)		
Capitals X ln(Export) x MKP3							-0.003	-0.005		
							(0.008)	(0.011)		
ln(Dist. trade) x ln(Export) x MKP4									0.002	0.002
									(0.002)	(0.002)
Capitals X ln(Export) x MKP4									0.003	0.011
									(0.008)	(0.012)
Constant	-32.302	-54.480*	-30.252	-52.414*	-31.071	-52.974*	-33.467	-55.286*	-32.643	-55.223*
	(24.790)	(28.725)	(25.150)	(29.177)	(24.940)	(28.896)	(24.970)	(28.935)	(24.886)	(28.893)
Observations	1614	1614	1614	1614	1614	1614	1614	1614	1614	1614
R-squared	0.06		0.06		0.07		0.06		0.06	
IV Exogeneity Test Stat.		0.643		0.815		0.705		0.849		1.134
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors clustered for counties in the parentheses;* P<.1, ** P<.05, *** p<0.01

Table 3-10. The Result for the Effect of Market Policy: Import

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Uniform Effect		Continuous Expansion		Gradual Expansion		Temporary Contraction		Pro-market dummy	
	FE	2SLSFE	FE	2SLSFE	FE	2SLSFE	FE	2SLSFE	FE	2SLSFE
ln(Market) x ln(Import)	0.523***	0.950***	0.393***	0.719***	0.313**	0.539**	0.296*	0.445	0.469***	0.883***
	(0.166)	(0.332)	(0.148)	(0.278)	(0.149)	(0.267)	(0.172)	(0.308)	(0.162)	(0.309)
ln(Market) x ln(Import) x MKP1			0.002**	0.005**						
			(0.001)	(0.002)						
ln(Market) x ln(Import) x MKP2					0.003*	0.006**				
					(0.001)	(0.003)				
ln(Market) x ln(Import) x MKP3							0.003	0.006*		
							(0.002)	(0.004)		
ln(Market) x ln(Import) x MKP4									0.001	0.002
									(0.002)	(0.004)
ln(Population)	0.193	0.705	1.620	3.449	1.464	3.229	0.859	2.121	0.319	0.860
	(1.922)	(1.932)	(2.135)	(2.461)	(2.116)	(2.427)	(2.024)	(2.197)	(1.947)	(1.983)
ln(Precipitation)	0.504***	0.555***	0.509***	0.551***	0.508***	0.548***	0.506***	0.548***	0.504***	0.554***
	(0.169)	(0.169)	(0.168)	(0.172)	(0.168)	(0.171)	(0.168)	(0.170)	(0.169)	(0.170)
ln(Dist. trade) x ln(Import)	-0.565***	-0.730***	-0.410***	-0.530***	-0.273**	-0.354**	-0.161	-0.217	-0.469***	-0.628***
	(0.142)	(0.192)	(0.133)	(0.160)	(0.131)	(0.152)	(0.143)	(0.171)	(0.140)	(0.178)
Capitals X ln(Import)	-2.190***	-3.568***	-1.846***	-2.894***	-1.657**	-2.363**	-1.687**	-2.138*	-2.226***	-3.563***
	(0.746)	(1.323)	(0.672)	(1.101)	(0.685)	(1.047)	(0.787)	(1.175)	(0.749)	(1.243)
ln(Dist. trade) x ln(Import) x MKP1			-0.003***	-0.004***						
			(0.001)	(0.001)						

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Capitals X ln(Import) x MKP1			-0.006	-0.014*						
			(0.005)	(0.008)						
ln(Dist. trade) x ln(Import) x MKP2					-0.005***	-0.006***				
					(0.001)	(0.002)				
Capitals X ln(Import) x MKP2					-0.007	-0.019				
					(0.006)	(0.011)				
ln(Dist. trade) x ln(Import) x MKP3							-0.005***	-0.006***		
							(0.001)	(0.002)		
Capitals X ln(Import) x MKP3							-0.006	-0.017		
							(0.007)	(0.013)		
ln(Dist. trade) x ln(Import) x MKP4									-0.003*	-0.003
									(0.001)	(0.002)
Capitals X ln(Import) x MKP4									0.001	-0.000
									(0.007)	(0.012)
Constant	-32.302	-54.480*	-30.252	-52.414*	-31.071	-52.974*	-33.467	-55.286*	-32.643	-55.223*
	(24.790)	(28.725)	(25.150)	(29.177)	(24.940)	(28.896)	(24.970)	(28.935)	(24.886)	(28.893)
Observations	1614	1614	1614	1614	1614	1614	1614	1614	1614	1614
R-squared	0.06		0.06		0.07		0.06		0.06	
IV Exogeneity Test Stat.		0.144		0.426		0.620		1.406		2.119
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors clustered for counties in the parentheses; * P<.1, ** P<.05, *** p<0.01

4. Conclusion

This research analyzes the channels through which trade affects North Korean regional economies. Three channels of export−led growth, import−led growth, and marketization channel are examined and the effect of the market policy is considered. The findings of the research include three considerations.

First, the export−led growth channel is significant for the mining sector, and the ELG channel through light industry is insignificant in most of the specifications. Considering the insignificance of light industry and the nature of the mining industry that requires a relatively low level of technology, the ELG channel in North Korea is closer to a resource−led growth channel than the ELG effect of industrialized countries.

Second, the import−led growth channel is insignificant. Inputs import does not appear to contribute to regional economies through any industries. Although the North Korean government strove to recover the economy following the Arduous March by concentrating limited resources on core industries, the restoration of industrial production through inputs import appears partial and insubstantial.

Lastly, export and import positively affect regional economies through the marketization channel. This is a positive externality of trade. Although neither the government nor the participants of trade have aimed at expanding the market through trade, economic opportunities and autonomy expanded as trade increased, acting as catalysts for market growth. Market policies, regardless of whether pro−market or anti−market, do not affect the marketization channel effect of export, whereas pro−market policies accelerate the marketization channel effect of import.

Concluding Remarks

This dissertation investigates economic questions related to North Korean regional economies using satellite nighttime light data. Regional disparities, determinants of regional economic performance, the effect of sanctions, and the differential effect of trade across regions depending on uneven economic resources are the subjects explored in the three pieces of research.

The first chapter estimates regional level GDP per capita and assesses regional inequalities of North Korea at the county level. This is the first research to assess economic status and regional inequality at the county level. The findings reveal sizable inequality of North Korean regions and that the majority of the inequality stems from within-province, whereas only between-province inequality, mostly between Pyongyang and other provinces, has been emphasized.

In the second chapter, the determinants of regional economic performance in the Kim Jong-un era are analyzed using nighttime light as a proxy for economic performance. The research finds that market size and involvement in trade measured as the proximity to trade hubs contribute to higher light, whereas industries do not have significant effects. In addition, sanctions are shown to substantially reduce nighttime light and the effects of sanctions are greater in regions with large markets or near trade hubs. In contrast, regions near major wholesale markets appear to better cope with sanctions although the aggregate effect on the region is negative.

In the final chapter, the channel of trade effect on regional economies is investigated for 2001-2016, examining three hypotheses of export-led growth, import-led growth, and marketization channel. To rule out endogeneity, historical data from the Japanese colonial era are used as IVs for the market variable.

The results indicate that resource export and growth of markets in response to trade are the main source of benefit from trade. Conversely, inputs import does not appear to affect regional economies through any industry. The findings imply that the recovery of the North Korean economy from the Arduous March was mainly the result of resource export and market expansion.

Throughout the three chapters, two main findings can be drawn. First of all, markets and trade are critical contributing factors of regional economic performance. Chapter 2 finds that regions with larger markets and closer to trade hubs have higher economic levels. The representative example is Sinuiju city, which is estimated to have a higher GRDP per capita than Pyongyang in Chapter 1. The result of Chapter 3 that trade affects regional economies through the marketization channel also emphasizes the role of markets and trade, also finding that the two factors work complementarily.

Second, sanctions affect the core economic factors of the North Korean economy. Chapter 2 finds that the regions with large markets or near trade hubs are damaged more severely. This is congruent with the findings of Chapter 3 that trade and market activities have mutual effects. Moreover, the findings in Chapter 1 that the proportion of unlit counties increased prominently in the North Korea–China border regions after sanctions were implemented, and that inequality tends to decrease following sanctions supports the finding that regions that have benefited more from markets and trade suffer more from sanctions

Appendix

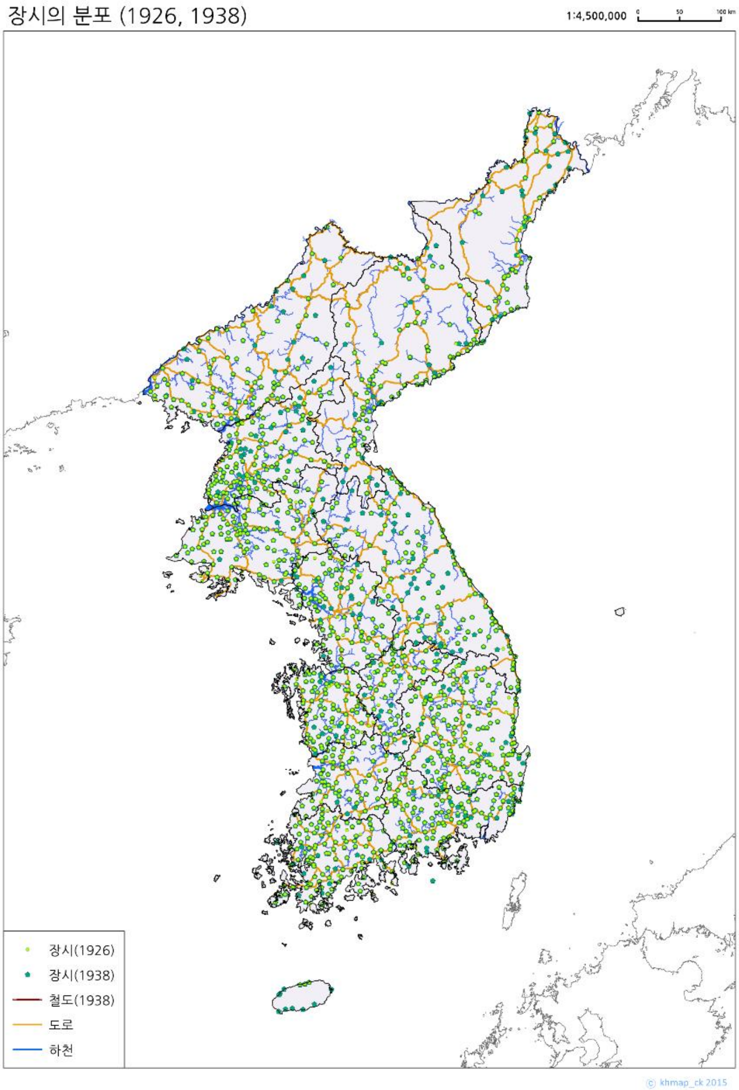

Figure A-1. Distribution of Markets in the Japanese Colonial Era

Source: 한국근대전자역사지도

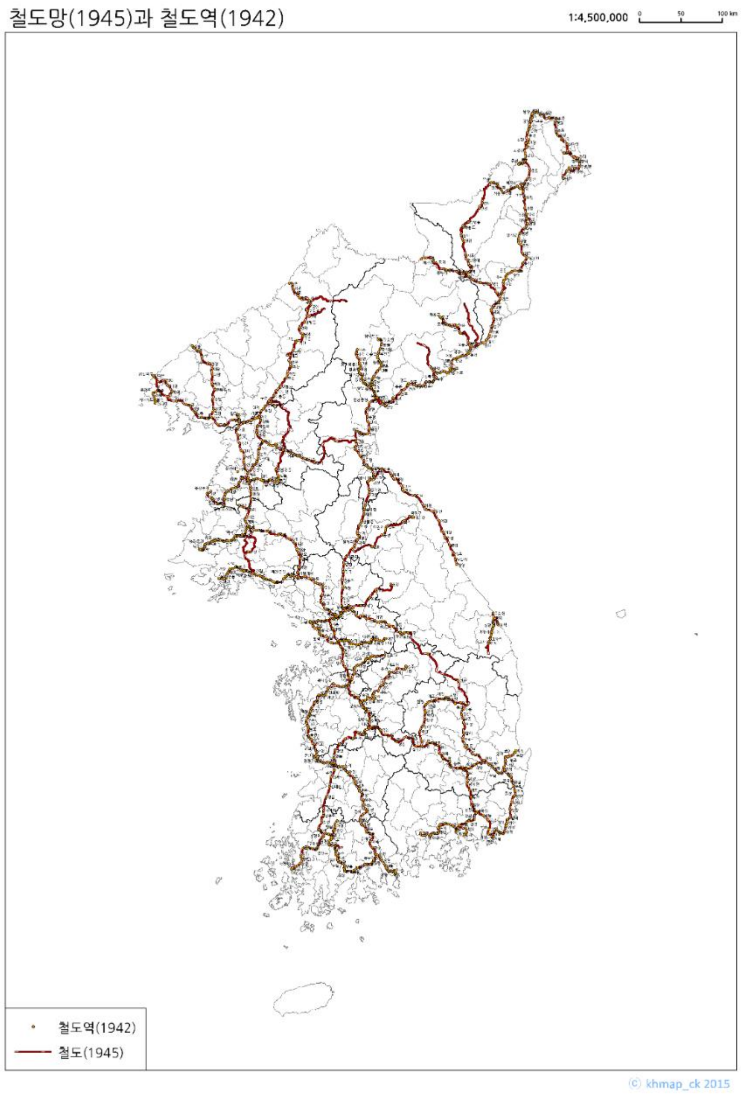

Figure A-2. Distribution of the Stations in the Japanese Colonial Era

Source: 한국근대전자역사지도

Table A-1. First Stage Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	ELG			ILG	Marketization: Export				Marketization: Import			
ln(IV market) x ln(Export)	0.664***				0.972***	0.437**	0.954***	0.664***				
	(0.193)				(0.277)	(0.193)	(0.271)	(0.193)				
ln(IV station) x ln(Export)	0.586***				0.806***	0.478***	0.823***	0.586***				
	(0.144)				(0.174)	(0.139)	(0.170)	(0.144)				
ln(IV market) x ln(Minerals Exp.)		0.627***										
		(0.210)										
ln(IV station) x ln(Mineral Exp.)		0.570***										
		(0.150)										
ln(IV market) x ln(Apparels Exp.)			0.091									
			(0.081)									
ln(IV station) x ln(Apparels Exp.)			0.191***									
			(0.049)									
ln(IV market) x ln(Inputs Import)				0.711***								
				(0.201)								
ln(IV station) x ln(Inputs Import)				0.632***								
				(0.153)								
ln(IV market) x ln(Import)									1.021***	0.455**	1.006***	0.676***
									(0.291)	(0.189)	(0.286)	(0.190)
ln(IV station) x ln(Import)									0.942***	0.545***	0.947***	0.710***
									(0.184)	(0.145)	(0.180)	(0.159)
Observations	1614	1614	1614	1614	1614	1614	1614	1614	1614	1614	1614	1614
R-squared	0.70	0.72	0.52	0.71	0.58	0.71	0.59	0.70	0.59	0.71	0.59	0.70

Note: Robust standard errors clustered for counties in the parenthesis. All other independent variables included in the second stage are included as regressors in the first stage.

* P<.1, ** P<.05, *** p<0.01

Table A-2. Results for ELG Using Mineral Export

	(1) FE	(2) FE	(3) FE	(4) 2SLSFE
ln(Light: F) x ln(Mineral Exp.)	-0.074			
	(0.056)			
ln(Mining: F) x ln(Mineral Exp.)	0.163***			
	(0.055)			
ln(Heavy: F) x ln(Mineral Exp.)	0.094			
	(0.060)			
ln(Light: W) x ln(Mineral Exp.)		0.011*		
		(0.006)		
ln(Mining: W) x ln(Mineral Exp.)		0.013***		
		(0.005)		
ln(Heavy: W) x ln(Mineral Exp.)		0.007		
		(0.006)		
ln(Light: C) x ln(Mineral Exp.)			0.080	0.006
			(0.061)	(0.089)
ln(Mining: C) x ln(Mineral Exp.)			0.193***	0.126*
			(0.053)	(0.074)
ln(Heavy: C) x ln(Mineral Exp.)			0.018	-0.058
			(0.062)	(0.088)
ln(Population)	1.587	0.436	1.698	2.797
	(1.894)	(1.887)	(1.991)	(2.256)
ln(Precipitation)	0.400**	0.429**	0.415**	0.406**
	(0.163)	(0.168)	(0.164)	(0.166)
ln(Dist. trade) x ln(Mineral Exp.)	-0.052***	-0.051***	-0.052***	-0.083***
	(0.013)	(0.016)	(0.015)	(0.030)
Capitals X ln(Mineral Exp.)	-0.009	-0.018	-0.017	-0.184
	(0.094)	(0.058)	(0.065)	(0.153)
ln(Market) x ln(Mineral Exp.)				0.079
				(0.065)
Constant	-27.981	-14.176	-29.066	-42.123
	(22.149)	(22.006)	(23.256)	(26.375)
Observations	1614	1614	1614	1614
R-squared	0.07	0.05	0.06	
IV Exogeneity Test Stat.				0.55
County FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Note: Robust standard errors clustered for counties in the parenthesis.
* P<.1, ** P<.05, *** p<0.01

Table A-3. Results for ELG Using Apparels Export

	(1) FE	(2) FE	(3) FE	(4) FE	(5) FE	(6) 2SLSFE
ln(Light: F) x ln(Apparels Exp.)	-0.151					
	(0.098)					
ln(Mining: F) x ln(Apparels Exp.)	0.313***	0.314***				
	(0.108)	(0.109)				
ln(Heavy: F) x ln(Apparels Exp.)	0.180*	0.067				
	(0.100)	(0.092)				
ln(Apparels: F) x ln(Apparels Exp.)		0.039				
		(0.068)				
ln(Light: W) x ln(Apparels Exp.)			0.012*			
			(0.007)			
ln(Mining: W) x ln(Apparels Exp.)			0.012**	0.012**		
			(0.005)	(0.005)		
ln(Heavy: W) x ln(Apparels Exp.)			0.008	0.008		
			(0.007)	(0.007)		
ln(Apparels: W) x ln(Apparels Exp.)				0.002		
				(0.003)		
ln(Light: C) x ln(Apparels Exp.)					0.161	-0.009
					(0.104)	(0.155)
ln(Mining: C) x ln(Apparels Exp.)					0.402***	0.250*
					(0.102)	(0.137)
ln(Heavy: C) x ln(Apparels Exp.)					0.036	-0.131
					(0.108)	(0.153)
ln(Market) x ln(Apparels Exp.)						0.181
						(0.112)
Observations	1614	1614	1614	1614	1614	1614
R-squared	0.09	0.08	0.06	0.05	0.08	
IV Exogeneity Test Stat.						0.18
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors clustered for counties in the parenthesis. Estimation results for the control variables are omitted.
* P<.1, ** P<.05, *** p<0.01

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< Database >

Annual VNL V2, Earth Observation Group.

Bank of Korea Economoic Statistics System.

Global Human Settlement Layer Dataset, European Commission.

Gridded Population of the World (GPW), v4, Socioeconomic Data and Applications Center.

International Trade Statistics Database, UN Comtrade.

KCNA Watch.

Korean Statistical Information Service.

OpenStreetMap Database, OpenStreetMap.

Rodong Newspaper Data, Korea Institute for Industrial Economics & Trade..

Version 4 DMSP-OLS Nighttime Lights Time Series, National Centers For Environmental Information.

World Development Indicator, World Bank.

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국문초록

본 논문은 북한의 시군 단위 지역경제의 현황 및 결정요인을 분석한다. 자료의 부재로 북한의 지역경제 연구는 매우 미흡한 실정이었으나, 기존에 사용되지 않았던 위성 야간조도 및 지리정보라는 새로운 자료를 활용하여 시장, 무역, 산업, 대북경제 제재가 지역경제에 미치는 영향을 실증적으로 분석한다.

첫 번째 연구에서는 김정은 정권 하 북한의 시군 단위 1인당 GRDP를 추정하고 불평등 수준을 평가한다. 북한의 GDP를 도시인구 비중에 비례하여 각 지역별로 배분한 후, 이와 야간조도 간의 관계를 도출하여 1인당 GRDP 를 추정한다. 또한 이를 바탕으로 지니계수 및 일반화된 엔트로피 지수를 도출해 북한의 불평등 추세를 분석하고 불평등 분해를 실시한다. 분석 결과 북한의 1인당 GRDP에는 지역간 상당한 격차가 있었으며, 도 단위에서는 평양대비 56-71%의 수준을 보였다. 그러나 불평등 분해 결과 도 단위의 격차보다 동일 도 내 시·군 간 격차에 따른 불평등이 약 87%를 차지하여 시·군 단위의 지역경제 연구가 매우 중요한 것으로 나타냈다.

두 번째 연구에서는 시장, 무역, 산업을 중심으로 김정은 정권 하 북한 지역 경제 수준의 결정요인과 대북제재가 지역경제에 영향을 분석한다. 이를 위하여 2013-2019년 야간조도 수준을 지역별 경제 수준의 대리변수로 사용하며, 일 부 지역에서 야간조도 값이 관측되지 않는 좌측중도절단(Left censoring) 문제가 발생함에 따라 OLS와 함께 토빗 모형을 사용한다. 분석 결과 시장 규모와 무역 중심지 접근성이 북한 지역경제수준에 긍정적 영향을 미치는 것으로 나타났으며, 산업변수의 영향력은 유의하게 나타나지 않았다. 한편, 대북제재는 북한의 지역 야간조도를 평균적으로 5.4% 감소시키며 특히 시장 활동이 활발하고 무역접근성이 높은 지역에 더 큰 피해를 입히는 것으로 나타났다. 한편, 제재 하에서 도매시장으로의 접근성이 높은 지역은 상대적으로 제재의 효과가 상쇄되는 것으로 나타났는데, 이는 제재 하에서 북한의 국내유통망이 상대적으로 중요해지고 한정된 자원이 도매시장으로 먼저 집중되기 때문인 것으로 해석된다.

세 번째 연구에서는 두 가지 종류의 야간조도 자료를 결합하여 2001-2016년 무역이 지역경제에 영향을 미치는 경로를 분석한다. 북한의 무역 자료는 연간 시계열만 존재하며 북한의 지역단위 변수들은 시간에 대해 불변하므로 무역변수와 지역변수 간의 교차항을 통하여 무역이 어떠한 경제적 특성을 가진 지역에서 더 큰 영향을 미치는지 분석함으로써 수출주도 성장, 수입주도 성장 및 시장화 촉진의 세 가지 가설을 검증한다. 이 때, 시장 변수에 내생성이 존재할 수 있으므로 일제강점기의 지역별 시장 및 기차역 개수를 시장의 도구변수로 사용하여 이를 해결한다. 분석 결과 수입주도 성장은 유효하지 않았으며, 수출의 경우 광업이 발달한 지역에 더 큰 긍정적 영향을 미치는 것으로 나타났다. 또한 수출과 수입 모두 시장의 규모가 큰 지역에 더 큰 긍정적 영향을 미치는 것으로 나타나 무역이 시장의 성장을 촉진하고, 시장이 지역경제를 성장시키는 긍정적 외부효과가 중요한 역할을 한 것으로 나타났다. 수출의 시장을 통한 영향은 시장 정책과 무관하였으나 수입의 경우 친시장 정책이 심화될수록 긍정적 외부효과가 강화되었다.

이상의 결과는 종합적으로 2000년대 이후 및 김정은 정권 하에서 북한 지역경제 성장의 주요 동력은 시장과 무역 및 그 둘 간의 상호작용임을 보여준다. 김정은 정권하는 물론 고난의 행군 이후 북한 경제의 회복기에도 지역별 시장 발전 수준 및 무역 참여도가 지역 경제수준에 큰 영향을 미쳤다. 또한 2017년 이후의 UN 안보리 대북제재가 북한경제에 부정적 영향을 미쳤으며, 특히 북한의 핵심 성장동력인 시장과 무역에 큰 피해를 입히므로 상당한 실효성을 가짐을 시사한다.