North Korea's Economic Growth Revisited with New Capital Estimates

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Abstract

This study aims to estimate the capital stock in North Korea from 1955 to 2018, based on the PIM, and then to explain its economic growth. The capital stock is estimated by decomposing it into construction assets and facilities assets.

Estimates show that North Korea's capital stock increased rapidly from 1955 to 1989, then decreased significantly in the 1990s, and recovered since the 2000s. The capital stock estimate as of 2018 stands at 24% higher than that in 1989. The capital stock to GDP ratio as of 2018 is around 3.9 times, which is higher than 3.0, the ratio commonly observed in many advanced economies. The estimated share of facilities capital within total capital is only 8% as of 2018, which compares with the corresponding rate (32%) during the 1970-1990 period in South Korea.

Growth accounting analysis shows that North Korea achieved a rapid input-led growth in the early stages of economic growth, but has since shown stagnant or sluggish growth, due mainly to a drop in total factor productivity. It suffered from the economic crisis in the 1990s, and after 2000 the low growth pattern was maintained as productivity continued to remain sluggish amid a lower input growth rate. Since 2017, the economic growth rate has plummeted due to a further drop in the input growth rate and a significant drop in productivity in the wake of sanctions. We believe that the negative GDP growth rate during the so-called "Arduous March Period," and the low growth seen in succeeding periods that has been characterized by idle capacity with a poverty trap, can be explained by a Harrod (1939)-Domar (1946) model based on the Leontief production function as outlined in Barro and Sala-i-Martin (1995).

As North Korea's growth conditions have deteriorated significantly due to the embargo on capital goods, it is required to improve its system that promotes productivity, efficiency and creativity through innovation in the ownership structure and management of farms and enterprises. More favorable foreign relations and an active opening policy are also necessary to attract foreign investment and technology, which is essential for human and physical capital accumulation and the resulting economic growth.

Despite the estimates of this study, efforts should continue to be made to compare the historical accumulation process of individual assets, to calculate deflators, and to enhance the accuracy of production data used in estimating economic growth. In particular, the capital stock estimates in this paper should be understood as preliminary figures, as it is linked to work to improve the estimation of North Korea's other macro statistics.

Keywords: North Korea, Capital Stock, Perpetual Inventory Method, Growth Accounting Analysis, Capital Productivity
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Ⅰ. Introduction

The factors such as labour, capital, technology and institutions are the core components to determine long-term economic growth of a country. Many countries have tried to achieve a better economic life through quantitative increase, qualitative improvement, or efficiency enhancement of each of these. In case information about these factors is provided sufficiently, it is possible to analyze the existing growth process of a country and to present a realistic plan to enable sustainable growth of the country.

However, it is difficult to obtain these information in North Korea compared to other countries. It is known that North Korean authorities do not provide official data related to them, and even if they do that, the data tends to be only fragmented or exaggerated rather than actual situations. As such, the lack of reliable data is the first difficulty that researchers always face when studying North Korea.

Under these conditions, this paper tried to estimate the capital stock in North Korea that is needed to primarily study North Korea's economic growth. The estimated capital stock may be used not only to analyze the growth factors of the economy of North Korea, but also to evaluate its existing economic policies, to estimate its development costs, and to estimate the effects of development plans.

Capital stock, in general, is used in estimating national wealth, producing consumption of fixed capital or analyzing causes of economic growth of a country, but it is well known that many countries face a lot of difficulties in its estimation. In case of North Korea, the estimation can be connected to the process of reproducing and reinterpreting its macro statistics. Reconstruction of North Korea's economic growth and trade data, obtaining fixed investment and computing appropriate deflators are related to the job. Meanwhile, this paper combined several ongoing studies in order to estimate North Korea's capital stock. Capital goods import data was quoted from Kim and Kim(2022), production of domestic capital goods was linked to value-added of heavy and chemical industry and quoted from Cho and Kim(2021).

The previous representative studies on North Korean capital stock estimation can be referred to Cho(1993) and Kim(2002). Later works can be viewed as kind of simple extension of Kim(2002)'s method. This paper also depends, in large part, on his work.

This paper, in estimating North Korea's capital stock, can be said as differentiated from prior studies in the following aspects. First, while previous studies estimated only capital stock as a whole, this paper estimated it by dividing into construction assets and facilities assets. Through this, the information could be revealed in which assets North Korea heavily invested by period. Second, it was presented transparently how North Korea's fixed investment by asset could be calculated. Third, several parameters necessary for estimating capital stock such as initial capital stock or depreciation rate of each asset were proposed. Although the parameters presented in this paper may not be completely accurate, it can be used as a reference material in conducting similar research in the field later. Fourth, the calculation errors of capital stock estimation in prior studies were corrected. For example, Kim (2002) or Kim et al. (2007) estimated capital stock as the following route: calculation of nominal investment → estimation of the nominal capital stock by the perpetual inventory method(PIM); → estimation of the real capital stock by a deflator. However, this paper corrected the route: estimation of the nominal investment → estimation of the real investment by a deflator → estimation of the real capital stock by the PIM → computation of nominal capital stock by reflation through a deflator.

The result of the estimation in this paper is summarized as follows: first, North Korea's fixed assets as of 2018 was estimated to be about 3.9 times GDP. The reproducible fixed capital, mainly observed in developed countries, was about three times GDP; the reason why the capital to GDP ratio of North Korea was so high is that the scale of the economy, the denominator, showed small; it may be said that the result was derived because the North Korean economy had not grown well enough. Second, the estimates showed that the construction assets to GDP ratio was 358%, and the facilities assets to GDP ratio was 33% as of 2018. The facilities assets accounted for about 8% of these two assets at the time, which means that the accumulation of facilities assets was significantly sluggish compared

to construction assets. Third, the series of estimates showed that North Korea's fixed assets were accumulated rapidly at the early stage of development, then plunged after the high point in 1989, and increased steadily again since the 2000s. Fourth, in case of following the assumption of unexpected capital loss in North Korea during 1990s as assumed in this paper, it was found that capital stock per capita as of 2018 was similar to the level of 1990. However, it needs to be confirmed that the assumption is reasonable. Accordingly, the Cobb-Douglas function was introduced to estimate the production function of North Korea, and then capital stock was derived ex post by substituting the labour input and GDP in that function. As a result, ex post estimates of capital stock derived from the production function showed a very similar level and movement to the ones based on some assumptions on capital loss during the 1990s. Fifth, the growth accounting was put in place through economic growth rate estimates in Cho and Kim(2021) together with this paper's estimates of capital stock and labour input; it was found that North Korea achieved an input-led growth in the early stage of economic growth, but since then, its economic growth stagnated, or economic recovery showed a sluggish trend, due to sustained decrease in total factor productivity as a major factor. Sixth, since the economic crisis in the 1990s, the North Korean economy can be interpreted as showing a kind of poverty trap and idle capital; it can be, in the sense, explained as a Harrod-Domar growth model based on the Leontief production function as described in Barro and Sala-i-Martin(1995).

On the other hand, despite this paper's trial, estimation of capital stock for North Korea should be supplemented in various aspects. First, the estimation results in this paper need to be compared with the microscopic estimation results. For example, for construction assets, if changes in stock are compared with investment in buildings such as houses, factories, schools, and government offices, or with the estimates of build-up of railway, road, power, urban development, etc., their accuracy may be cross-checked. Second, it is necessary to pay more attention to compiling data that can be used as a deflator; it is because capital stock can be measured properly when real investment series are computed with a relevant deflator. In particular, it seems necessary to pay priority attention to how to deflate trade data with consistency. Third more efforts should be put to increasing the accuracy of the quantity information used in estimating the economic growth rate. It should be recognized that quantity information can be used as an important source for estimating investment and capital stocks as well as economic growth in North Korea. Finally, the estimated capital stock in this paper should be understood as a provisional one under progress. It is because the estimates of North Korean economic growth may be incomplete, and this paper uses them as an unavoidable precondition.[1)]

This paper consists of the followings: In Chapter II, our literature survey is presented on capital stock estimation of North Korea. In Chapter III, a general methodology of capital stock estimation is mentioned and our plan to apply it to North Korean data is shown. Above all, it is emphasized that the fixed assets are divided into construction assets and facilities assets, and the way is explained how they are implemented in North Korean data. Chapter IV presents the estimation results of capital stock as a whole and by asset. Various indicators are presented such as the scale of the total amount, the ratio to GDP, the scale per capita, etc., and the robustness of the estimation results is also reviewed. In addition, the growth accounting is implemented with new capital stock estimates, and a tentative explanation for North Korean economic growth is suggested through a theoretical model. In Chapter V, the implications that can be obtained from the estimation results are derived, and also limitations of this paper and matters to be improved in subsequent studies are presented.

[1] Various discussions have been presented regarding North Korea's economic growth estimates. For Example, Kim(2019a) suggested that the economic growth rate in the Kim Jong-un era could be raised by an average of 1% point, if the trend of marketization would be fully reflected. Yang and Zang(2017) evaluated that if North Korea's coal production is estimated appropriately and upwardly during the first half of 2010s, and then the growth rate during the Kim Jong-un era could rise by an annual average of 1 % point. In addition, Kim(2019c) suggested that if North Korean marketization and rebuild up of the state-run economy were comprehensively reflected, the growth rate of North Korea could be raised by 2% points per year since the mid-2000s. We would like to express our gratitude to Dr. Sukjin Kim for his comments on the above discussion.

Ⅱ. Literature survey

Previous representative studies in estimating capital stock in North Korea include Jo(1993) and Kim(2002). Jo(1993) estimated North Korea's labour and capital input based on the Cobb-Douglas production function in order to evaluate North Korea's labour productivity. As for the investment data required to estimate capital stock, the basic construction expenditure[2)] was used among the budget items of North Korea. Similarly to Jo(1993), Kim(2002) constructed time series of fixed investment using budget data of North Korea. In addition, considering that North Korea's budget revenue (or expenditure) shows a high correlation with GNP, nominal GNP of North Korea was newly estimated from 1954 to 1989 assuming that the relationship between the budget expenditure growth rate and nominal GNP growth rate was linearly connected during the relevant periods. His work is very meaningful in that the relationship among North Korea's budget data, GNP, and investment was derived, and then North Korean long-term growth and capital stock were newly estimated from 1954 to 1989. Moreover, his method of capital stock estimation played as a starting point for follow-up research.

Subsequent studies commonly used Kim(2002)'s capital stock series for 1954 to 1989, and for post-1989, capital series were extended through researchers' own assumptions. For example, while Jo(2013) used the estimates of capital stock by Kim(2002) from 1965 to 1989, he extended them with new estimates of his own from 1990 to 2012. Meanwhile, Kim et al.(2007) found through growth accounting that North Korea's total factor productivity is very low over a long period of time, which is a major factor in explaining low economic growth rates of North Korea, and their analysis used Kim(2002)'s capital estimates. In Shin and Kim(2018), the effect of Kaesong Industrial Complex on the economy of South and North Korea was estimated through growth accounting in which their capital data was estimated by extending Kim(2002)'s estimates. For post-1989 periods, North Korea's investment was assumed to remain at 20% of the government's budget, and then capital stock was extended by applying the PIM. Meanwhile, Hong(2010) and Lee(2017) estimated North Korea's capital stock by assuming that only depreciation occurred in North Korea without any new capital investment during the economic crisis of 1990-98, and that investment was made only as much as depreciation in the recovery since 1999. Jung (2016) estimated the North Korea's investment using the "basic construction expenditure" in the North Korea's budget data from 1970 to 1989 and also using the amount of capital goods import from China for post-1989 when fixed investment was not possibly constructed from budget data due to changes of the budget system in North Korea.

When all things considered from prior studies, most studies used capital estimates by Kim(2002) for pre-1990. For post-1989, capital stock of North Korea was estimated by constructing fixed investment series under researcher's own assumptions. Therefore, the main variable for capital stock estimation for post-1989 is how to establish investment series for the period.[3)] The method considered in prior studies was the application of a certain % of North Korea's budget expenditure, or paying attention to capital goods import from China, etc. However, as the budget system of North Korea was changed in

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[2] North Korea's budget expenditure item is as follows: expenditure on the people's economy, expenditure on social and cultural policies, expenditure on national defense, expenditure on state; expenditure on people's economy is again divided into basic construction expenditure, floating funds, price subsidies, industrial / business support funds, rural support funds, science and technology development project costs, urban management project costs, local project costs, and external economic project costs. Among them, basic construction expenditure refers to the expenses to create new or expand existing fixed assets and is understood as a similar concept to our fixed investment (Jo, 1993). *The Dictionary of Fiscal and Monetary Affairs*(1995) explains that "Basic construction expenditure includes construction and assembly work costs, facilities costs, costs of preparation for production, furniture and fixtures costs and other basic construction costs". Here the basic construction expenditure needs to be understood as a concept including both construction and facilities investment.

[3] Of course, in order to estimate the real capital stock denominated in North Korean won (KPW), how to apply the deflator and the exchange rate in addition to fixed investment are also important variables to be considered.

1990s, it is difficult to estimate the amount of fixed investment in North Korea by using budget data. In addition, North Korea's fixed asset investment needs to cover imports from abroad and domestic production of fixed assets as well.[4)] Considering these points, the method of estimating fixed investment series in North Korea since 1990 still has much to be improved. In this paper, long series of North Korean fixed investment was newly estimated in consideration of limitations of prior studies; based on this flow data, capital stock of North Korea from 1955 to 2018 was estimated.

<Table 1> Prior Studies on estimation of capital stock in North Korea

	Period	Estimation method and assumptions	Major results
Jo(1993)	1965-1990	·1954: the capital-to-production ratio is assumed to be the same for South and North Korea. ·1960-1965, 1971-1976: fixed investments are estimated based on the basic construction expenditure of budget data. ·Depreciation rate 5%	(Base year: 1985) ·Capital stock: KPW 9.4 billion (1965), KPW 175.1 billion (1990)
Kim(2002)	1954-1989	·Capital to GNP ratio in 1953: 0.7 ·Depreciation rate 5% ·Fixed investment: basic construction expenditure is used until 1976, and from 1977, half of "expenditure on people's economy plus defense expenditure" is applied.	(Nominal capital stock) ·KPW 941 million (1954), KPW 109,324 million (1989)
Kim et al. (2007)	1954-1989	·The fixed investment series and depreciation rate are the same as Kim(2002), but the capital to GNP ratio for 1954 was applied as 0.6 instead of 0.7 of Kim(2002). ·Their finding is that "the prime cause of slow economic growth was extremely low or even negative total factor productivity".	(Average annual growth rate of capital stock) ·1954-1960: 12.6-13.0% ·1960-1980: 6.8-8.0%
Hong(2010)	1954-2008	·1954-1989: same as that of Kim(2002) ·1990-1998: new fixed investment = 0 ·1999-2008: fixed investment is made by the amount of depreciation (5%).	·In view of factoral productivity, decline in capital productivity is pointed out as the primary cause in structural changes in North Korea's economy.
Jo(2013)	1990-2012	·Initial stock as of 1990: Annual average growth rate (8.95%) of Kim(2002)'s capital stock during 1985-1989 is applied to his capital stock for 1989. ·Depreciation rate 5% ·Investment: 30% of total budget in the 1990s, its 20% since 2000.	(Base year: 2005) ·Capital stock: USD 97.6 billion (1990), USD 1,295.1 billion (2012)
Jung(2016)[1)]	1970-2012	·Investment: basic construction expenditure (1970-1989), capital goods import from China(1990-2012) ·Deflator: Consumer Price Index of China	·It is verified that import and export from/to China and fixed investment (capital goods import) are important factors for North Korea's economic growth.
Lee(2017)	1970-2016	·1979-1989: Kim (2002) ·1990-1998: new fixed investment = 0 ·1999-2016: fixed investment is done by the amount of depreciation (5%)	·1970-2016: The capital income ratio of North Korean is estimated as 0.3413.
Shin and Kim (2018)	1970-2016	·1979-1989: Kim (2002) ·Since 1990, fixed investment is assumed to occupy 20% of the fiscal budget.	·In 2016, the capital stock in North Korea was 1.4% of that in South Korea.

Note: 1) The paper mainly focused on economic growth in North Korea, and it estimated fixed investment as one major variable in the growth model, but it did not directly estimate capital stock.

[4] If parts are imported and assembled in North Korea, they are not recognized as imported capital goods, but capital goods domestically produced in North Korea.

Ⅲ. Methodology of Capital Stock Estimation in North Korea

1. Information Required for Capital Stock Estimation

In this paper, capital stock of North Korea was estimated by applying the PIM. In the case of North Korea, data is too insufficient, so it was inevitable to choose a method that could estimate capital stocks with limited information. The PIM is a method of estimating capital stocks based on a stock(*K*)-flow(*I*) identity as shown in Equation (1). In other words, capital stock (K_t^E) at the end of time t is calculated by subtracting the depreciation (δ *x* K_{t-1}^E + $\delta/2$ *x* I_t) incurred during time t from the value of adding capital stock (K_{t-1}^E) at the end of the previous time *t-1* to the investment (I_t) of time *t*. Therefore, in order to estimate the capital stock (K_t^E) at the end of time *t*, information on the capital stock (K_{t-1}^E) at the end of time *t-1*, the investment (I_t) of time t and the depreciation rate (δ) is required. Here, ^{E} denotes the end point of time *t*.

$$K_t^E = (1-\delta) \times K_{t-1}^E + I_t - \delta/2 \times I_t \qquad (1)$$

First, in case of the fixed investment (*I*), its series needs to be computed as long as possible. This is particularly applicable to construction assets such as housing, factories, public facilities, roads, and railways. For example, if the average life span of these assets is 50 years, assuming a normal distribution type of disposal, it is necessary to have at least a 100-year investment series to properly estimate capital stock. Next, the depreciation rate (δ) of the asset is also required to calculate the depreciation amount during the period. Capital stock (K_t) and investment (I_t) have a time subscript *t*, but it is not shown in the depreciation rate. This means that the depreciation rate is assumed to be time(or age)-invariant. Finally, Equation (1) requires a capital stock (K_{t-1}^E) at the end of the previous time for each period. Logically, this can be retroactive to an infinite past, but in reality, it is necessary to estimate the value in advance at a certain past time. This is called the initial capital stock (K_0^E).

2. Asset Classification, Depreciation Rate, and Initial Capital Stock

[Fixed asset boundary to be estimated: construction assets and facilities assets]

In prior studies such as Kim(2002), capital stock was estimated only at the level of capital as a whole, and it was not estimated in further detail. This paper, in contrast, attempted to estimate capital stock by dividing it into construction assets and facilities assets. Sadly, however, intellectual assets[5] were not estimated in this paper due to lack of necessary basic data. Naturally, various sub-asset categories are included within these asset groups, but they were not classified into sub-levels due to lack of relevant information as well. In addition, the estimated target of this paper was limited to fixed capital in a narrow sense, and, accordingly, inventories, land, underground resources, and standing timber were not estimated.[6]

[Estimation of the depreciation rate (δ) by asset]

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[5] Intellectual assets are abbreviations of intellectual property products in the System of National Accounts (SNA) and include research and development, software, mineral exploration, and creations, etc.

[6] In the SNA, assets are identified as a means of production and value storage, and they are largely classified into financial assets and non-financial assets. And, non-financial assets are classified into produced assets and non-produced assets, depending on whether they were produced by humans. Produced assets are classified into fixed assets and inventory assets, and non-produced assets are classified into land, underground resources, and standing timbers, etc. For more information, please refer to EC et al. (2008) or Bank of Korea (2014).

The depreciation rate by asset used in capital stock estimation was calculated by the declining balance rates (*DBRs*) method. The DBRS method is a way of indirectly computing the depreciation rate ($\delta=DBD/T$) using the asset's average life (T) and the DBR. First of all, the life of each asset is assumed to be 40 years for construction assets and 15 years for facilities assets.[7] The durability of buildings or social overhead capital structures in North Korea could be relatively weak, so the service life of construction assets was assumed to be 40 years. Since machinery and transportation facilities are valuable assets in North Korea, they tend to be used for a long period of time, but they are usually more likely to be secondhand goods rather than new, and difficult to maintain. Therefore 15 years is applied to facilities assets.

Next, for DBR of each asset, the information identified in Korea's capital stock estimation is applied. Accordingly, as shown in Table 2, 1.32 for construction assets and 2.02 for facilities assets were applied as DBRs, respectively.[8] These parameters were derived from capital stock estimation in Korea as an average value between 2006 and 2015.

Table 2 shows the depreciation rate by asset calculated by dividing the DBR by its life. As a result, the depreciation rate of construction assets was estimated as 3.30% and that of facilities assets as 13.47%, respectively. Interestingly, even if a different depreciation rate is applied by asset, there is no noticeable difference from the case of applying the depreciation rate at the level of one asset as a whole. For example, in this paper, different depreciation rates were applied for each asset, but the average depreciation rate for both assets altogether between 1956 and 2018 was 4.8%, which was not much different from the 5% applied by Kim(2002). In addition, when reviewed by period, 5.2% were found in 1956-1989, and 4.3% were found in 1990-2018.

<Table 2> Estimation of asset's depreciation rate using declining balance rate

	Construction Assets	Facilities Assets
Service life (T)	40	15
Declining balance rate (DBR)	1.32	2.02
Depreciation rate(δ)	3.30%	13.47%

Note: Author's assumptions

[Estimation of the initial capital stock (K_0)]

This paper aimed to estimate capital stock in North Korea since 1955, and the initial capital stock (K_0) was assigned as of the end of 1955. According to OECD (2009), there are two methods for estimating initial capital stock for countries with insufficient fixed investment data. As in Kohli (1982), it can also be approximated by accumulating real investments (net of depreciation) over the years preceding the initial time point (t_0); as in Dadkhah and Zahedi (1986) or Pyo (2008), there is another method of applying an econometric search technique to indirectly estimate the initial stock.

More specifically, the first method was proposed by Kohli (1982), approximating the initial capital stock by accumulating real investments over the years prior to the initial time point (t_0). Assuming a geometric age-efficiency curve, productive capital stock (or net capital stock) in the initial base year (t_0) is computed as the cumulative amount of depreciated investment up to the previous year, as shown in Equation (2).

$$W_{t0} \approx [I_{t-1} + (1-\delta)I_{t-2} + (1-\delta)^2 I_{t-3} + \ldots] \quad (2)$$

[7] The life to which several OECD member countries apply in estimating capital stock is shown in OECD (2009).

[8] The DBR usually indicates how many times the reciprocal (1/T) of life decreases in value. For example, when an asset reaches its average life of 10 years, a residual value of 11% of its initial value generally corresponds to a DBR of 2, and a residual value of 20% corresponds to a DBR of 1.5. If the residual value is only 3%, the DBR increases to about 3.

A valid assumption should also be introduced for the long-term growth rate, and the simplest one is to match growth rates of real investments with those of GDP. One option is to obtain any stable growth rate for fixed investment as indicated as θ below. And in case this is substituted into Equation (2) under the assumption of $I_t=I_{t-1}(1+\theta)$, the following Equation (3) is derived. Through Equation (3), the initial capital stock can be estimated using the level of fixed investment at the initial time point (I_t), the long-term investment or GDP growth(θ), the depreciation rate(δ), etc.

$$\begin{aligned}&[I_{t-1}+(1-\delta)I_{t-2}+(1-\delta)^2I_{t-3}+\ldots]\\&=I_{t-1}(1+(1-\delta)(1+\theta)+(1-\delta)^2(1+\theta)^2+\ldots)\\&=I_{t-1}(1+\theta)/(\delta+\theta)\\&=I_t/(\delta+\theta)\end{aligned} \quad (3)$$

In addition, OECD (2009) introduced an indirect estimation method for the initial capital stock. This is a method of estimating the Cobb-Douglas aggregated production function by linking it to the capital stock (K) - investment flow (I) identity according to Dadkhah and Zahedi (1986). Dadkhah and Zahedi (1986) presented another method which assumes that capital is a constraining factor of production in the absence of labour input data.[9)]

Pyo (2008) implemented initial stock estimation for 11 developing countries according to the Dadkhah and Zahedi (1986) and according to the Kohli (1982). Looking at the results, in half of those countries, both estimates yielded very similar results. However, in the other half of countries, both estimates generated large gaps. Therefore, OECD (2009) recommends to compare the robustness of estimates, by estimating initial capital stocks with various methods mentioned above.

Meanwhile, in case of North Korea, considering that there is not enough information to apply this technique, the results identified in the process of capital stock estimation for South Korea were simply cited. Accordingly, initial stock of construction assets was given 120% of GDP and its 30% for facilities assets as of the end of 1955, as shown in Table 3. In choosing the year 1955 as the initial benchmark, it was first considered that large-scale asset losses due to the Korean War might have been restored to a considerable level. In addition, as shown in Statistics Korea (1998), it was also considered that the Gross National Product per capita in South Korea and North Korea showed almost same of $65 and $66, respectively.

<Table 3> Initial Capital Stock for each asset

	Construction Assets	Facilities Assets
Initial Stock(K_0)/GDP Ratio(%) as of the end of 1955	120%	30%

Note: Author's assumption based on the South Korean case

3. Constructing Fixed Investment Series (I_t)

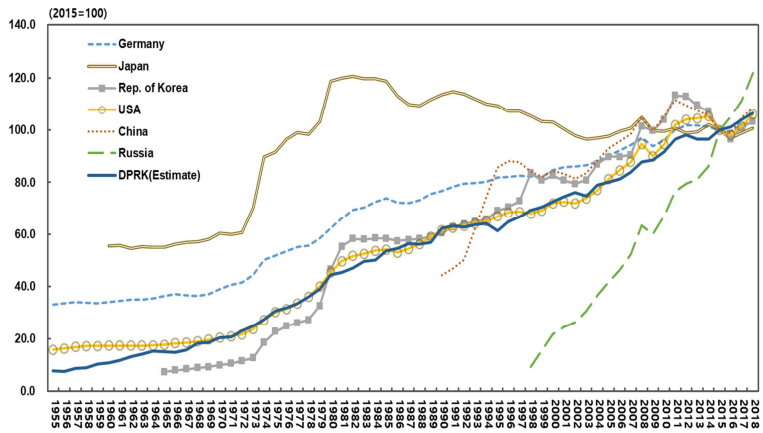
In order to estimate North Korea's capital stock, it is necessary to secure annual investment (fixed capital formation) data by asset in addition to the parameters mentioned above. However, it is a general process for this investment to be estimated first in nominal terms and then to be computed later in real terms with an appropriate deflator. However, in case of North Korea, estimating an appropriate deflator itself is a very difficult task due to lack of data. Considering this, in this paper: (1) with 1990 as the base year, construction investment and facilities investment are first estimated for

9 For more details, refer to OECD(2009), pp.222-226.

1990; (2) subsequently, computation is followed of yearly growth rate of real investment for each asset; (3) by applying these growth rates, the real investment series are established before and after 1990 for both assets. Here, setting 1990 as the base year means assuming that the nominal GDP is equal to the real GDP for this year, and that the nominal and real investment are also the same for this year. The total amount of construction and facilities investment in 1990, the base year, was estimated by referring to the method in Kim (2002). In other words, total of construction and facilities investment in 1990 were considered to be 50% of expenditure on the people's economy plus military expenditure[10] in North Korea's budget data.[11] Meanwhile, this paper's fixed investment series shows mostly a similar level and pattern with Kim (2002), there are some variations before 1977 due to differences in the estimation method.[12]

In addition, capital goods import from abroad was here deflated by a GDP deflator with lack of data so this paper, in the sense, also has limitation for the deflator issue as usually revealed in prior studies. The GDP deflator before 1990 in this paper was calculated by dividing the nominal GDP estimated by Kim (2002) by the real GDP estimated by Cho and Kim(2021). Meanwhile, an additional deflator is needed to deflate capital goods import after 1990; in this paper, German manufacturing producer price index was quoted, which showed a high correlation with the GDP deflator estimates of North Korea during 1955 – 1990(refer to Figure 1).[13]

<Figure 1> GDP Deflator Estimates for North Korea and Manufacturing PPIs of Major Countries



Source: Author's estimate

[Building Real Construction Investment Series]

In the case of construction investment, it may be said that it is almost consistent with the output of

[10] Military expenditures are explained to be spent on developing the defense industry, fortifying the nation's land, managing and modernizing the entire army, and arming the entire people, but details are not clear.

[11] Of the total expenditure on the people's economy and military, North Korea's basic construction expenditure rose from 41.6% in 1971 to 65.1% in 1976. Kim (2002), however, lowered the ratio to 50% from 1977 to 1989 based on the situation of harder capital goods import and worsening economy. In this paper, it is assumed that 50% is maintained even in 1990.

[12] For example, in case of 1977-1989, this paper's series is completely consistent with Kim (2002). However, from 1955 to 1976, authors' estimates have some gaps with those in Kim (2002).

[13] When the correlation coefficient is computed with North Korea's GDP deflator estimates for the 1955 ~ 1990 period, the German manufacturing PPI was 0.992, the US manufacturing PPI 0.987, the Japanese manufacturing PPI 0.943, and the Korean manufacturing PPI 0.977. Of course, since this is not strictly analyzed in consideration of the instability of the time series data, there is a possibility that a spurious regression may be implied between them. However, the fact that North Korea imported a lot of machinery and transportation facilities from West Germany in the past can be seen in prior studies (Choi, 1992, p.270; Kim, 1994, p.194). Recently, although North Korea's main trading partner is China, it was assumed that Germany's manufacturing producer price index may be more suitable than China for capital goods.

the construction industry. In other words, construction companies that have received orders generate output (sales) through constructing buildings or civil engineering because it is the same as investing in these structures from the perspective of the orderer.[14] In the sense, estimating construction investment is the same as estimating output of the construction industry.

On the other hand, in case there is information on the time t value-added of the construction industry (VA_{CONST}) and the time t ratio of value-added to gross output in the construction industry(s_{CONST}), it is possible to estimate time t gross output of the construction industry(V_{CONST}), as shown in Equation (4). In this regard, construction investment in 1990, the base year, was estimated assuming the ratio of value-added to gross output to be 50% in the construction industry during the same year. Because North Korea has maintained the socialist planned economy for a long time, it would be difficult to apply any ratio observed in the market economy. Therefore, this paper assumed it as 50%, in consideration of the case of the Soviet Union. If a depreciation[15] is added to the Net Material Product (NMP) of the Soviet Union construction industry presented in Becker (1972), Gross Material Product (GMP) of the industry could be computed. Now, if the GMP is divided by the Gross Social Product (GSP) of the construction industry, the ratio of value-added to gross output in the Soviet Union construction industry could be computed as an average of 49.2% in 1958 ~ 1968. In addition, we would like to clarify that despite it is reasonable for the value-added ratio of the construction industry to change little by little every year, the same rate was granted for all periods due to the absence of appropriate information.

$$V_{const,t} = IC_{const,t} + VA_{const,t}$$
$$V_{const,t} = VA_{const,t} / s_{const,t} \quad (4)$$
(here, $s_{const,t} = VA_{const,t} / V_{const,t}$)

In addition, series of construction industry output before 1990 was retroactively extended by liking its growth to an increase of cement production in North Korea as explained in more detail by Cho and Kim(2021). The fact was considered that the correlation coefficient between construction investment and cement production in the 1970s-1990s was 0.992 in South Korea. The series after 1990 was obtained by linking to the value-added growth of the construction industry in North Korea estimated by the Bank of Korea. In case of cement production before 1990, data were omitted in several years; for these years, the estimates were used by linear interpolation or interpolation at a certain growth rate.

[Building Real Facilities Investment Series]

In case of facilities investment, the investment series was estimated based on the commodity flow method. In other words, the total supply of certain capital goods in a country is produced (Q_{mach}) domestically or imported (M_{mach}) from abroad; the capital goods supplied in this way are consumed (C_{mach}) or invested (I_{mach}) domestically, or exported (X_{mach}) abroad to constitute total demand. Maybe domestic consumption of capital goods would be minimal. Therefore, after re-arranging this logic, it may be said that the investment in capital goods is approximated by adding domestic production and net import of capital goods as shown in Equation (5). In case domestic production and net import of capital goods are available, the series of the entire facilities investment could be obtained by adding up both data. The amount of facilities investment in 1990, the base year, was calculated by subtracting the construction investment in 1990 from total construction and facilities investment in 1990 (approximated as 50% of expenditure on the people's economy plus military expenditure in North Korean budget data).

[14] This fact can be confirmed through South Korean data. Computing from the Bank of Korea's national account statistics, the correlation coefficient between the output of the construction industry and construction investment from 1970 to 2016 is almost 1.0.

[15] It was assumed to be 5% of GSP.

$$
\begin{aligned}
&Q_{mach,t} + M_{mach,t} = C_{mach,t} + I_{mach,t} + X_{mach,t} \\
&I_{mach,t} = Q_{mach,t} - C_{mach,t} + M_{mach,t} - X_{mach,t} \\
&I_{mach,t} \approx Q_{mach,t} + (M_{mach,t} - X_{mach,t})
\end{aligned}
\qquad (5)
$$

According to Equation (5) identified by the commodity flow, facilities investment is estimated by adding domestic capital goods investment and net imported capital goods.[16] Domestic capital goods can be expected to basically accompany the production of machinery and transportation facilities manufacturing industry. In this paper, the series of domestic capital goods before 1990[17], was obtained by linking to the value-added growth in the heavy chemical industry estimated in Cho and Kim(2021) and after 1990, it was extended by linking to the value-added growth in the heavy chemical industry compiled by the Bank of Korea. In addition, the net import of capital goods was borrowed from the new estimation by Kim and Kim(2022) which was referred to Choi (1992), the Korea Investment and Trade Promotion Agency (KOTRA), and UN Comtrade data. As a deflator for net import before 1990, the North Korea's GDP deflator, estimated by Cho and Kim(2021) was used, and for post-1989, the German manufacturing PPI was used, as mentioned above. Table 4 summarizes how the real investment series of construction and facilities assets were estimated.

<Table 4> Constructing Real Fixed Investment by Asset

	Construction and Facilities Investment	Construction Investment	Facilities Investment
1955-1989	Construction investment + facilities investment	Retrospective estimation linked to growth rate of cement production	Real net capital goods import is separately computed each year Domestic capital goods production before 1990 is linked to growth rate of GDP in heavy and chemical industry
1990 (Base year)	Assume 50% of expenditure on the people's economy plus military expenditures in budget data * Method adopted by Kim(2002)	Value-added of the construction industry in 1990 / 0.5 (= assumed value-added to gross output ratio)	Facilities investment is derived from construction and facilities investment minus construction investment Domestic capital goods investment is computed from facilities investment in 1990 minus net capital goods import
1991-2018	Construction investment + facilities investment	Construction investment after 1990 is linked to growth rate of value-added in construction industry	Real net capital goods import is separately computed each year Domestic capital goods production after 1990 is linked to growth rate of value-added in the heavy and chemical industry

[16] The authors devised an alternative method of estimating facilities investment by subtracting construction investment after estimating the total amount of basic construction expenditure, as done in Kim (2002), but it was not adopted because there were many cases where facilities investment had a negative (-) value around 1960.

[17] Of course, this assumes that price fluctuations in North Korea are accurately reflected in exchange rate changes. In order to deflate the amount of capital goods imported in dollars to North Korea, the amount in dollars must first be converted into North Korean won (KPW) through multiplication of the exchange rate, and then the amount in KPW needs to be divided by a deflator. Meanwhile, in the sense that fluctuations in exchange rate can be seen as the result of simultaneous changes in North Korea's domestic prices as well as foreign country's prices, if North Korea's price changes are accurately reflected in the exchange rate, the relevant deflator of imported capital goods to North Korea can be interpreted as the export price index of the foreign counter-party country. Here, the German manufacturing PPI was considered to correspond to this.

IV. Estimation Results of Capital Stock in North Korea

1. Series of Fixed Investment

For the PIM to be applied, it is utmost important to establish long investment series. In particular, in this paper, fixed investment[18] was calculated by construction and facilities asset. In addition, the real investment series of North Korea was established from 1955 to 2018 on a basis of 1990 prices. It should be noted that the explanation below is based on evaluation with the prices in 1990. As a result of estimation, North Korea's investment in fixed assets has continued to increase since 1955 to about KPW 14.1 billion in 1990, but since then, it decreased rapidly and is estimated to be around KPW 5.6 billion in 1998. In 2000s, North Korea's investment in fixed assets increased again, reaching KPW 12.6 billion in 2016, which was similar to the investment level in mid-1980s. Since 2017, when major exports began to be blocked and restrictions on capital goods began to be imposed due to high-intensity sanctions against North Korea, investment in fixed assets has decreased, and as of 2018, the total investment in fixed assets in North Korea was estimated at KPW 10.4 billion.

Looking at fixed investment by asset, both construction and facilities assets continued to rise from 1955 to the late 1980s, but then slumped sharply until the late 1990s, when the former Soviet Union and Eastern European socialist countries collapsed and North Korea suffered a serious economic crisis known to the world outside as Arduous March. More specifically, construction investment averaged KPW 4.3 billion in the 1960s, and in the 1970s and 1980s, the average annual real investment increased to KPW 5.8 billion and KPW 8.7 billion, respectively. The trend of investment in North Korea's construction assets before 1990 is considered to be in line with the following backgrounds: the housing construction had steadily increased from the 1960s to the mid-1980s[19]; the construction of large public buildings was actively carried out around the 70th birthday of President Kim Il-sung (April 15, 1982) and the 13th World Festival of Youth and Students in July 1989[20]; activities were carried out aggressively to restore and establish the railways of North Korea in the 1960s and 1970s.[21] However, investment in construction assets, after peaking at KPW 10.4 billion in 1990, was estimated to have plummeted by 58% in eight years to 4.3 billion won in 1998.

Meanwhile, the average annual real investment in facilities was KPW 1.6 billion before 1970, but it started to increase gradually since 1970 and the actual investment was KPW 4.5 billion in 1974. The facilities investment in North Korea, after decrease for several years since 1975, rebounded in the 1980s, and peaking at KPW 4.1 billion in 1989. Since the 2000s, both construction and facilities investments increased steadily, and in 2016, North Korea's real investment was estimated at KPW 9.8 billion for construction and KPW 2.8 billion for facilities, respectively.[22]

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18 In the national account system, the total fixed investment is estimated by adding construction investment, facilities investment, and investment for intellectual property products. Also the total investment is estimated by adding changes in inventories and net acquisition of valuables to total fixed investment. The investment series in this paper is total fixed investment that does not take into account the intellectual property products and changes in inventories and net acquisition of valuables.

19 Choi et al.(2015), p.12.

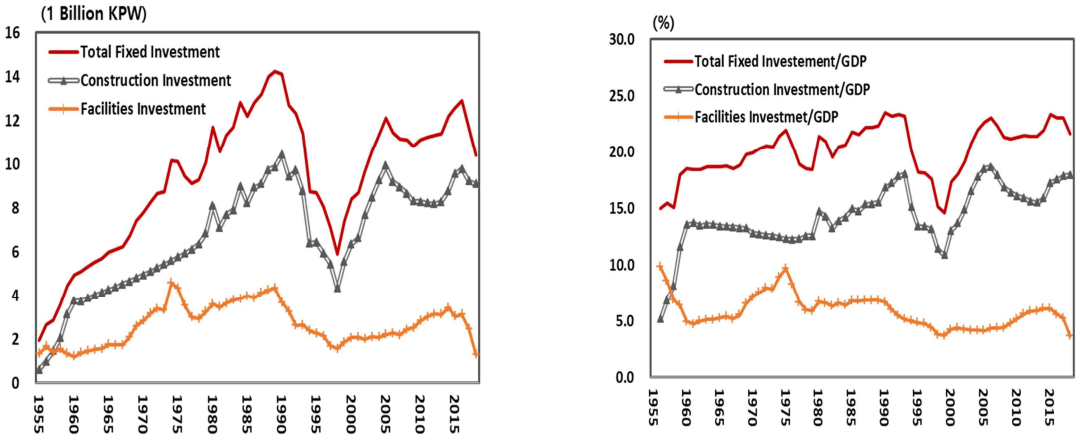
20 Joo(1994), pp.275–342.

21 Kim(2019b), pp.33-37.

22 Please refer to Appendix A1 for fixed investment estimates by assets in North Korea from 1955 to 2018.

<Figure 2> Real Fixed Investment by asset and its ratio to GDP

(Real investment) (Investment to GDP ratio)



Source: Author's estimate

As shown in Figure 2, the ratio of fixed investment to GDP in North Korea is estimated to stand at 21.8% in 1975,[23] which was 21.3% on average in the 1980s, and the average in the 2000s was 20.2%, which is below that in the 1980s. After 2010, the average investment to GDP ratio was 21.6%, which is similar to the level of the mid-1980s. Here, since North Korea's nominal GDP and total fixed investment series, in this paper, were mostly borrowed from the estimates of Kim(2002), the ratio of fixed asset investment to GDP is generally consistent with his analysis in case of pre-1990.

Looking at the ratio of investment to GDP by asset, the ratio of construction investment fluctuated around 13.2% on average during 1960 ~ 1979, and then increased to 14.8% on average in the 1980s. However, the ratio, which had fallen to 10.9% in 1999 with severe economic difficulties, recovered somewhat since the 2000s and was 16.8% on average from 2006 until recently. The ratio of facilities investment to GDP peaked at 9.5% in 1975, when North Korea's capital goods imports surged. However, it fell sharply in the 1990s, reaching only at 3.1% in 1999, and then gradually rising to 5.2% annually from 2010 to 2016. In recent years, the ratio of facilities investment was lowered significantly due to restrictions on capital goods import caused by sanctions against North Korea from the international community, and it is estimated to be 3.5% as of 2018.

The investment in facilities assets is further divided into overseas imports and domestic production.[24] As shown in Figure 3, real investment through imports, until the 1950s, amounted to 1.1 billion won (1955-59 yearly average), accounting for 74% of total facilities investment. However, owing to North Korea's heavy industry priority policy, real investment from domestic production increased from KPW 1.1 billion in the 1960s to KPW 3 billion in the 1980s. As a result, domestic production and investment accounted for 80% of total facilities investment in North Korea in the 1980s. After severe economic difficulties in 1990s, domestic production and domestic investment remained in 2000s at a certain level at an annual average of KPW 1.5 billion. Meanwhile, overseas imports averaged KPW 500 million annually in the 2000s, but increased to KPW 1.3 billion annually between 2010 and 2016.

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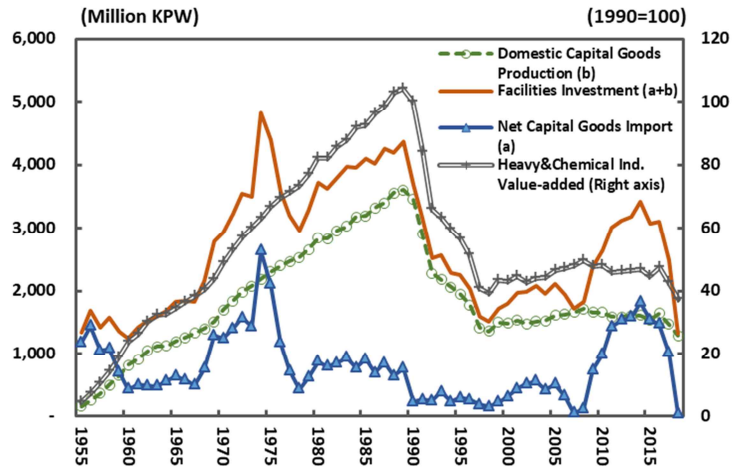
[23] Since 1975, the investment in facilities decreased due to the worsening of external trade, and the ratio of total investment has decreased somewhat, but it rebounded since 1980, and the ratio of fixed investment to GDP in 1990 stood at 23.3%. Since then, investment in fixed assets also decreased along with the rapid economic deterioration, and the total investment ratio tended to decrease.

[24] In order to convert US dollar-denominated net import data into North Korean won (KPW), this paper used North Korea's trade exchange rate. However, since the "July 1 Economic Management Improvement Measures" in 2002, North Korea's official exchange rate jumped significantly and disconnectedly. Therefore, in this paper, the trade exchange rate for 2001 was applied the same even after 2002. In this case, the assumption of the constant exchange rate may be said to be the limitation of this paper. In the future, in case the long series data of the North Korean exchange rate is secured by considering the economic structural change, the estimates in this study would be upgraded.

<Figure 3> Facilities Investment in detail (in real term)



Note: 1) The net import data (Kim and Kim, 2022) was deflated by the GDP deflator before 1990 and by German manufacturing PPI since 1990.
2) GDP index of heavy and chemical industry also comes from Cho and Kim(2021).

The trend of North Korean facilities investment through overseas imports and domestic production shows a close relationship with changes in North Korea's external trade environment and growth in production of North Korea's heavy industry. First, looking at the changes in North Korea's external trade environment, North Korea increased its imports of capital goods through trade with Western developed countries such as West Germany and France in the early-1970s, but after 1975, trade with them decreased rapidly due to overdue trade payments.[25)] However, with the conclusion of a trade and economic cooperation agreement with the former Soviet Union in 1985, North Korea's imports of capital goods could increase again from 1986 to 1990.[26)] Since 2010, the import of capital goods such as mining facilities and transportation vehicles increased significantly due to the rapid increase in North Korea's mineral exports (Kim et al., 2020). The change in North Korea's foreign trade conditions peaked in 1974 and then decreased, then recovered in the 1980s, and is in line with the trend of overseas imports of facilities investment, which increased significantly from 2010. Meanwhile, after the Korean War, North Korea adopted a growth strategy based on the heavy industry-priority development, and the heavy industry sector grew rapidly. In particular, North Korea focused its capabilities on the construction of heavy industries, focusing on the machinery industry, and in the early 1980s, to solve the problem of insufficient factory machinery, a "campaign to increase factory machinery"[27)] was held to produce necessary machine tools on its own. According to the Korea Finance Corporation (2010), North Korea produced large machines in the late 1980s and promoted the diversification of machine tools, reaching a level where exports as well as domestic supply were partially possible.[28)] As such, high investment in the heavy industry seems to have had a continuous

[25] Shin(2000) explained as follows: North Korea's trade deficits had widened sharply with Western advanced countries in 1970s because the former had sharply increased imports with the latter but demand from the latter for non-ferrous metals, which had previously been a major export item of the former, had declined due to a slowdown in Western economies driven by the oil shocks. In addition, it is explained that while the international market price for non-ferrous metals plunged at the time, the price of machinery that is an imported product, rose, making North Korea unable to pay the trade on time after the summer of 1974.

[26] North Korea adopted the Joint Venture Law in 1984 and signed an economic cooperation agreement with the Soviet Union in 1985, and Eberstadt (1998) evaluated that it was the latter that had a more significant impact on the increase in capital goods imports between 1986 and 1990.

[27] It was a movement of all people in North Korea, requiring factories and businesses in all sectors of the economy to produce one or more machine tool in addition to the basic tasks, in order to promote socialist industrialization and technological revolution in North Korea (Korea Finance Corporation, 2010).

[28] In the mid-1980s, Numerical Control (NC) machine tool production bases were built, and in the late 1980s, large machinery, such as 6,000 ton press and 20 units of large lathes, was produced in the general-purpose machine tool sector.

impact on the increase in domestic production of North Korean facilities assets until the 1980s. However, the growth centered on the heavy industry[29] caused an imbalance between industries in North Korea,[30] and it might have caused a slowdown in the growth rate of heavy industry and a downturn in the North Korean economy[31] since the 1970s.

2. Capital Stock

[Estimation results]

After establishing long-term investment series for the construction and facilities asset, the capital stock (K_t^E) at the end of time t was estimated by applying the depreciation rate (δ) to the capital stock (K_{t-1}^E) at the end of the previous time and the investment (I_t) of current time, as shown in Equation (1). Here, for the initial capital stock (K_0) and the depreciation rate, it was assumed that the ratio of capital stock to GDP in North Korea in 1955 was the same as that of South Korea.[32] As for the depreciation rate, it was set by asset through assuming a life and declining balance rate, in consideration of the characteristics of construction and facilities assets, respectively.

Figure 4 shows the ratio of North Korea's fixed asset stock to GDP, estimated in this paper. Series estimation 2 (capital stock 2, construction asset 2, and facilities asset 2) was estimated, in consideration of the possibility that capital losses may have occurred rapidly at a time when economic difficulties were severe during the period of “Arduous March” in the 1990s. For example, Unheung Smelter, located in Yanggang-do, was a first-grade enterprise that produced copper and sulfuric acid by processing copper refining, but during the period of “Arduous March” in the mid to late 1990s, many workers artificially disposed of machinery and parts, reaching the level where the factory could no longer operate.[33] It may be estimated that capital losses due to such artificial disposition or lack of maintenance during the period of Arduous March were made nationwide. In this study, Series 2 was conducted by applying the assumption that the stock of construction asset and the stock of facilities asset declined by the same decrease rate of GDP during the period of 1990 ~ 1998. As with the investment series, it should be noted that the following description is based on the estimates valued at 1990 prices.

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[29] According to Cho and Kim(2021), North Korea's heavy and chemical industry grew high at 17.3% until the 1960s, and slowed to 5.8% and 3.4% in the 1970s and 1980s, respectively. According to Goto(1981), the average annual growth rate of the producer goods industry corresponding to the heavy industry was 22.7% between 1957 and 1966, and decreased to 7.9% in the 1970s. The growth rate of North Korea's heavy and chemical industry from 1956 to 1966 by Cho and Kim(2021) was estimated to be 20.6%, confirming that it was similar to the estimate of Goto(1981).

[30] In addition to the imbalance between heavy industry and other industries, there was an imbalance within the machinery industry sectors. Since North Korea focused on machine tools, mining and construction machinery, and railway vehicle industries, the technological backwardness of precision machinery and electrical and electronics industries was intensified, which caused the limitation on the development of the machinery industry (Korea Finance Corporation, 2010).

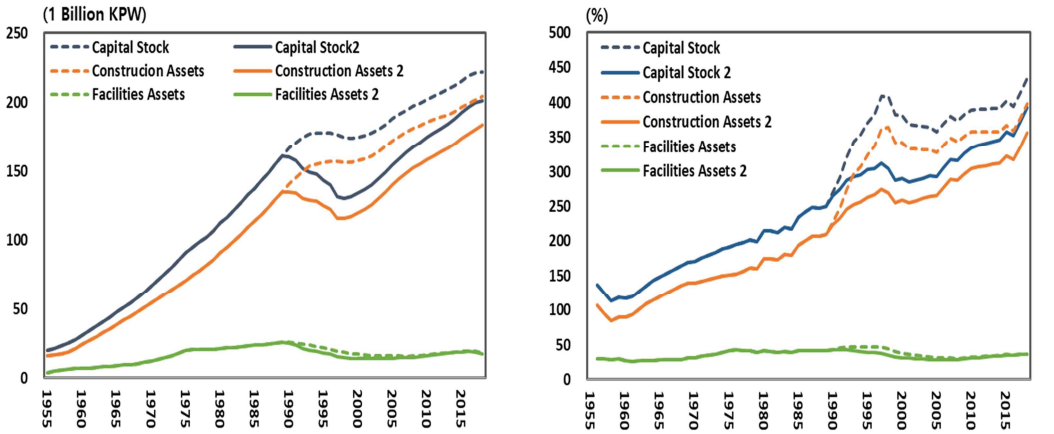
[31] North Korea's heavy industry-priority policy was based on the judgment that it could increase productivity and lead to growth in agriculture and light industry through preemptive development of the heavy industry sector that produces means of production. However, the excessive growth of the heavy industry sector resulted in a deepening imbalance between industries, and in the long run, a lack of connection between heavy industry and agricultural and light industries, and, moreover, accumulation of economic inefficiency. As a result, the growth rate of production in the industry sector of North Korea slowed from the 1970s and showed a negative trend from the 1980s (Kwon, 2004).

[32] In case the initial capital stock of North Korea was reset at the ±50% level of the South Korean capital stock in 1955, it was found that the level of North Korean capital stock converged after the 1970s regardless of the initial value.

[33] Please refer to the “LIBERTY KOREA POST” (2019.7.24). Other articles also confirm the cases where machinery and parts of factories were greatly damaged in North Korea during the period of Arduous March. For example, the dismantling of the "August Smelter" located in Yanggang-do (The Radio Free Asia, April 24, 2013), and the "September Steel" case in Uiju-gun, Pyonganbuk-do (The DAILY NK, October 16, 2006).

<Figure 4> Capital Stock Estimates of North Korea (valued at 1990 prices)

(Real capital stock) (Capital stock to GDP ratio)



Source: Author's estimate

Looking at the estimation results based on Series 2 which considered the rapidly deteriorating economic condition in the 1990s, North Korea's fixed capital stock peaked at KPW 162 billion in 1989. The stock of construction and facilities asset stood at KPW 136.9 billion and KPW 25.1 billion, respectively, with both assets showing relatively an approximate ratio of 85: 15. Meanwhile, after 2000, North Korea's capital stock began to rebound, recording KPW 162.4 billion in 2007, recovering to the level in 1989. As of 2018, the capital stock in North Korea was estimated at KPW 200.2 billion. However, in 2018 the construction asset increased to KPW 184 billion, which was higher than the level of 1989, the facilities asset was estimated to be KPW 16.2 billion, below the level in 1989. Even in 2016, before the intensity of sanctions against North Korea increased, North Korea's facilities asset was 17.6 billion won, indicating that it remained at a level that did not recover its high point in 1989.[34] On the other hand, the compositional ratio of construction and facilities asset gradually widened from the ratio of 8:2 in the 1980s and the early 1990s, to the ratio of 9:1 since the 2000s. Considering that South Korea's facilities asset accounted for 32% of fixed assets between 1970 and 1990, North Korea did not seem to have invested enough in new facilities assets for the purpose of economic recovery and industrial reconstruction even after Arduous March when North Korea suffered from severe losses of machinery.[35] Of course, in the late 2000s, large-scale new facilities were invested in chemical and metal industries with the aim of building a strong and prosperous country by 2012,[36] and the estimation results of this paper showed that the facilities asset increased from the late 2000s. More specifically, the facilities asset stock, which had continued to show a negative growth rate since 1990, was converted to a positive growth rate since the mid-2000s, showing a positive growth rate of 3.1% in 2009, and an average annual increase of 3.9% from 2010 to 2014. This seems to have had a positive effect on the growth of the manufacturing industry, and as a result, it seems that it contributed to a positive production growth[37] in the light industry and heavy and chemical industries between

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34 Please refer to Appendix A2 for the stock estimates of fixed assets in North Korea in 1955 ~ 2018.

35 In the case of South Korea, the proportion of construction assets, facilities assets, and intellectual property products accounted for 79%, 14%, and 8%, respectively, in 2018 which means the proportion of facilities assets decreased compared to the 1970s and 1980s when economic growth was promoted. In North Korea, facilities assets accounted for 18% of the total fixed assets in the 1970s and 1980s, but the proportion decreased from 13% in the 1990s to 9% after the 2000s.

36 Yang et al. (2012) evaluated that as North Korea resumed large-scale investment in chemical plants in the late 2000s, production activities in the large-scale facilities manufacturing field became somewhat active. However, he explained that if such investment is performed in facilities that does not improve economic efficiency or meet technological capabilities, it is likely to result in a waste of resources.

37 According to the Bank of Korea's estimate, North Korea's manufacturing growth rate from 2012 to 2014 was 1.1% per year, of which light industry and heavy and chemical industry grew 2.5% and 0.6%, respectively.

2012 and 2014. However, as discussed earlier, the actual investment in facilities assets is estimated to be less than that in mid- to late-1970s, and the investment level is still insufficient compared to the past peak level.

Meanwhile, based on Series 2 assuming capital loss in the 1990s, North Korea's capital stock was estimated to be 3.9 times GDP as of 2018. The scale of capital, about three times that of GDP, is mainly observed in developed countries[38]; the reason why North Korea's capital coefficient is so high can be understood because the scale of the economy, the denominator, did not grow enough rapidly. In other words, it can be said that it reveals the low productivity and inefficiency of the North Korean economy. Meanwhile, the ratio of construction assets to GDP was estimated to be 358%, and the ratio of facilities assets was estimated to be 33%. As shown in Table 5, looking at the ratio of capital stock to GDP in South Korea by asset, the ratio of North Korean facilities assets to GDP as of 2018 is similar to 34% of South Korea's level in 1971 ~ 1975. What is unusual is that the ratio of South Korea's construction asset stock to GDP during the same period was 81%, showing a very large difference from North Korea's 358%. In other words, considering the scale of the economy, it can be assumed that the imbalance between North Korea's facilities assets and construction assets is severe. This structure is associated with problems such as aging of the electrical grid and of machinery facilities, and is expected to worsen the possibility of a decrease in factory operation rate, low productivity of the North Korean economy, and increased inefficiency of investment.

<Table 5> Capital Stock to GDP ratio for South Korea

(Unit: %)

	1971~75	1976~80	1981~85	1986~90	1991~95	1996~00	2001~05	2006~10	2011~18
Capital Stock	116	129	156	166	202	253	262	300	321
Construction Asset	81	86	101	109	145	186	201	238	254
Facilities Asset	34	41	52	52	49	56	46	44	45
Intellectual Property Products	2	2	3	5	8	11	14	18	22

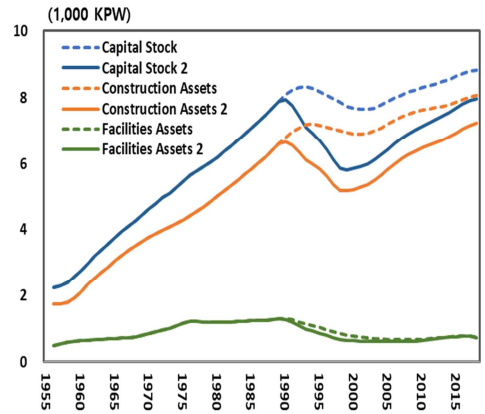
Source: Economic Statistics System of Bank of Korea (http://ecos.bok.or.kr)

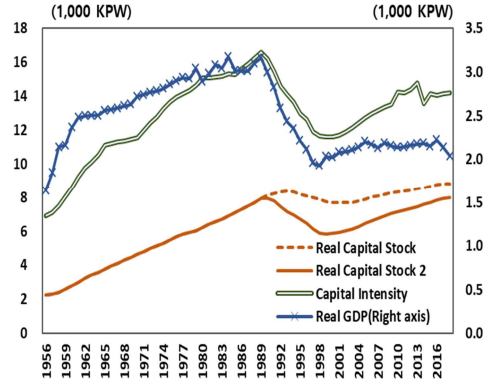
Meanwhile, Figure 5 examined the changes in economic scale and volume of capital in consideration of North Korea's population. First, the capital stock per capita was estimated in consideration of the total population, and in 1990, the construction asset and the facilities asset reached a high of KPW 6,800 and KPW 1,200, respectively, and the fixed assets including both reached a high of KPW 8,000. With the severe economic deterioration in the 1990s, per capita capital stock plunged to KPW 5,800 in 1999 and began to recover after 2000, and as of 2018, North Korea's fixed capital stock is estimated to be KPW 7,900 (construction asset KPW 7,200 and facilities asset KPW 700) which is similar to the level in 1990. The fixed capital stock of North Korea exceeded the previous high (1989) in 2007, while the capital stock per capita approached the level in the late 1980s as of 2018 after the plunge in the 1990s, indicating that the previous high (1990) was not regained. Looking at the trend of capital intensity calculated by considering the labour-age population of North Korea (aged 16 or older, excluding soldiers) reconstructed in this study, the capital per worker in 2018 was KPW 14,000, which was estimated to be similar to the level in the late 1970s.

[38] Looking at the Bank of Korea's national account statistics, South Korea's net capital stock (on a normal basis) in 2018 is calculated to be 3.3 times GDP.

<Figure 5> North Korea's Capital Stock per capita, GDP per capita and Capita Intensity

(Real capital stock per capita) (Real GDP per capita, capital intensity)





Source: Author's estimate

Notes: 1) Real GDP per capita is calculated from the estimates of Cho and Kim (2021).
2) Capital intensity indicates capital stock2 to working-age population(UN statistics).

Meanwhile, real GDP per capita, capital stock per capita, and capital intensity were found to be on a similar trend, and as of 2018, North Korea's real GDP per capita was estimated to be KPW 2,000, which was around the level of the late 1950s. As of 2018, North Korea's per capita capital stock and capital intensity were at the level of the late 1980s and 1970s, respectively, while the real GDP per capita remained at the level of the late 1950s, reaffirming the possibility of low productivity in the North Korean economy.

[Robustness check: backward estimation of capital stock using the coefficient derived from production function estimation]

This study estimated the capital stock from 1990 to 1998 by assuming that capital was reduced by the negative economic growth rate in consideration of the significant loss of facilities assets in North Korea during the severe economic crisis in the 1990s (Capital Stock 2).[39] To confirm the robustness of this capital stock estimates in North Korea, authors also estimated capital stock in a different way by; first estimating the production function of North Korea, and inserting the labour force and real GDP data into the function, and then computing capital stock in reverse (Capital Stock 3).

Table 6 shows the result of estimating North Korea's labour productivity[40] from 1955 to 2018 assuming the Cobb-Douglas function. The capital elasticity of output was 0.41, which was significant at the significance level of 1%. In addition, the trend, which means technological progress and institutional efficiency, was estimated to be negative. As shown in Figure 6, it showed that capital stock 3, which was estimated inversely by substituting the estimated coefficient of the production function during the period, shows a trend generally similar to capital stock 2, which was estimated based on the PIM. However, in case of Capital Stock 3 estimated on the basis of the production function, it showed a much deeper decline and more rapid rebound in the 1990s.

[39] The "Capital Stock" in Figure 5 and the "Capital Stock 1" in Figure 6 are estimated by the PIM without making any particular adjustments to the possibility of capital loss in the 1990s.

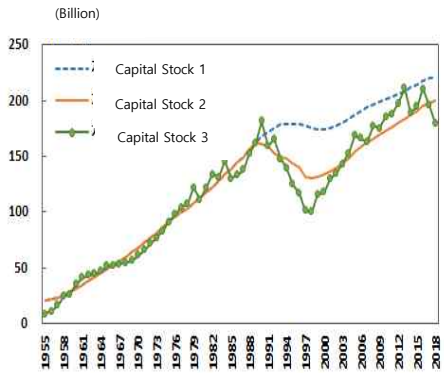
[40] Since the OLS estimate cannot derive a coincident estimate if there is a correlation between the capital intensity and the error term, 2SLS estimation was performed using the capital intensity of the t-2 period as an instrumental variable in this study. In addition, a dummy variable for 1955 ~ 1989 was added, when North Korea did not suffer from the severe economic decline.

<Table 6> Regression Analysis on North Korean Labour Productivity

	Dependent variables: Labour productivity
Capital intensity	0.41 (5.91)***
Trend	-0.01 (-7.17)***
Prior to 1989 = 1	0.18 (3.79)***
Constant term	0.91 (8.17)***
Observations	61
R2	0.97
F-statistics	15.505

Note: 1) In case F-statistics are greater than 10, it may be interpreted that there is a correlation between the instrument variable and the endogenous variable.
2) *** is significant at the significance level of 1%.

<Figure 6> Comparison of Capital Stock by Method



Note: Capital Stock 1 and Capital Stock 2 are estimated by the PIM, and Capital Stock 3 is inversely computed by the production function.

3. Growth Accounting

A country's economic growth is mainly achieved by increased input of labour and capital, and enhanced productivity growth such as changes in technology and institutions, which is usually computed as residual. This study analyzed the causes of North Korean economic growth from 1955 to 2018 using new capital stock estimates in three aspects.[41)] First, the quantitative and qualitative growth of each input factor such as labour and capital was observed. Second, the part that labour contributed to North Korea's economic growth was decomposed into quantitative and qualitative dimensions. Third, through the growth accounting analysis, the trend of each factor's contribution to GDP growth like capital, labour, and total factor productivity was observed.

First of all, quantitative growth of labour and capital can be examined through the ratio of labour force to population and capital stock per labour force (i.e., capital intensity). Meanwhile, labour productivity and capital productivity can be seen as variables representing qualitative growth of labour and capital input factors. Looking at Figure 7, the proportion of the labour force in North Korean population continued to rise from 36.1% in the 1960s to 53.9% after 2010.[42)] On the other hand, labour productivity (= real GDP per labour force) increased significantly until the early 1960s, but then stagnated or slightly decreased, and plunged in the 1990s. In the 2000s, labour productivity improved somewhat, but after 2010, it decreased again. In other words, it can be seen that the quantitative labour input continued to increase, but qualitative growth was not accompanied. Meanwhile, North Korea's capital intensity (capital stock per labour force) continued to rise until the 1980s, but reversed to decrease as the amount of capital was reduced during the period of Arduous March. Since 2000, the capital intensity rebounced, but in recent years, labour force increased somewhat faster than capital, indicating that the capital intensity slightly decreased. Capital productivity (computed as GDP per capital stock), interpretable as qualitative growth of North Korean capital input, increased significantly in the late 1950s but then has continued to decline since the 1960s. Although investment in fixed assets increased in the 1970s and 1980s and the North Korean economy also showed growth,

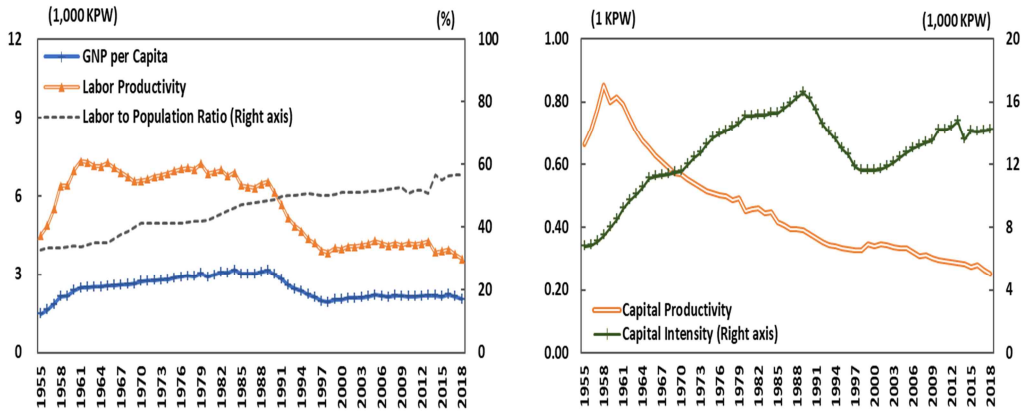
41 The economic growth rate of North Korea used in this analysis was borrowed from Cho and Kim (2021). Consistently with the method by the Bank of Korea to estimate North Korea's GDP growth rate, Cho and Kim classified the North Korean economy into seven industries, estimated each industry's growth rate, and then applied the Laspeyres' Chain Index Formula to estimate North Korea's overall growth rate in 1956-1989.

42 Please refer to Appendix A3 for the estimation of the labour force in North Korea.

the continued decline in capital productivity suggests a problem in terms of capital utilization.

<Figure 7> North Korea's per capita GDP, and Quantitative and Qualitative Growth of Labour and Capital

(Labour) (Capital)



Source: Author's estimate

Second, North Korea's GDP growth can be decomposed in consideration of the total population and the labour force. As shown in Equation (6), GDP (Y) growth rate is decomposed into total population (T) growth rate and per capita GDP (Y/T) growth rate. In addition, the contribution of labour to per capita economic growth can be decomposed into quantitative and qualitative aspects as shown in Equation (7) below. In other words, the per capita GDP (Y/T) growth rate is decomposed into the growth rate of the labour force to population ratio (L/T) and the growth rate of labour productivity (Y/L), and the former can be interpreted as the quantitative growth of labour and the latter as the qualitative growth of labour.

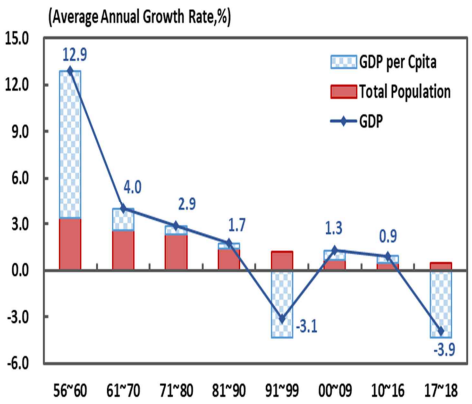
$$Y = T \times \frac{Y}{T} \quad (6)$$

$$\frac{Y}{T} = \frac{L}{T} \times \frac{Y}{L} \quad (7)$$

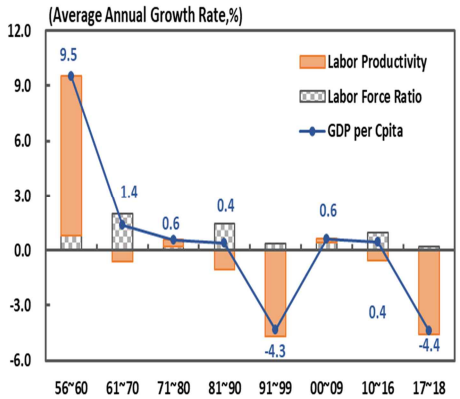
Figure 8 shows that North Korea's GDP growth was mainly due to the growth of the total population. It can be observed that growth in per capita GDP, which is closer to the improvement of the welfare level of each citizen, is also mainly due to an increase in the proportion of the labour force, not labour productivity. During the high growth period of North Korea in the late 1950s, North Korea's labour productivity grew significantly, but from the 1960s, North Korea's labour productivity continued to decrease or show a low increase rate. This shows that while North Korea's labour productivity slows, the increase in labour input, that is, mobilization of labour force, played a major role in driving North Korean growth. These results are consistent with the study of Kim(2002) who concluded that the increase in the proportion of the labour force contributed more to North Korea's per capita GDP growth than the growth of labour productivity.

<Figure 8> Factoral composition of North Korean GDP growth

(Growth in GDP) (Growth in GDP per capita)



Note: Using equation (6)



Note: Using equation (7)

Table 7 shows comparison between Kim et al. (2007)[43] and this study. From the mid-1950s to 1989, North Korea's GDP and per capita GDP growth rate were not so different and the characteristics of North Korea's economic growth were similar between two studies. First, looking at the GDP growth rate, the estimates of this paper and Kim et al. (2007) were 4.7% and 4.4%, respectively. When the GDP growth rate was decomposed into total population growth and per capita GDP growth, the contribution ratio for each factor contributing to GDP growth was close to 50:50 in this paper, and Kim et al. (2007) revealed that total population growth contributed a bit more. Meanwhile, over the period, the per capita GDP growth rate was 2.3% and 1.9% and the labour productivity was 1.1% and 0.3%, respectively. Both studies showed that the increase in the labour force ratio rather than labour productivity contributed more to the per capita GDP growth. However, this paper' GDP growth rate was somewhat higher and this paper's labour force ratio growth rate was somewhat lower than the estimates of Kim et al.(2007), therefore, this paper's labour productivity growth rate was estimated to be a little higher. As a result, North Korea's input-driven growth pattern was more pronounced in Kim et al.(2007).

<Table 7> Comparison of North Korea's GDP Growth Studies

(Average annual growth rate, %)

	GDP	GDP growth rate		GDP growth rate per capita	
		Total population	GDP per capita	Labour force to population ratio	Labour productivity
Estimates in this paper (1956-1989)	4.7	2.3	2.3	1.2	1.1
Kim et al. (2007)[1] (1954-1989)	4.4	2.5[2]	1.9	1.6[2]	0.3

Note: 1) Estimates II was referred to, which estimated North Korea's economic growth in consideration of hidden inflation.
2) Although it does not appear in Kim et al. (2007, p.574), it was re-calculated using the relationship: "GDP = Total population × GDP per capita " and " GDP per capita = Labour force to population ratio × Labour productivity."

Third, growth accounting analysis was conducted to examine North Korean economic growth factors by dividing them into external factors such as labour and capital input and internal factors such as technological innovation and institutional change. In this study, as shown in Equation (8), the Cobb-

[43] Kim et al.(2007) argues that it adjusted possible overestimation bias in North Korean economic growth rate estimated by Kim (2002) in consideration of the hidden inflation problem, which is commonly observed in socialist countries.

Douglas production function was assumed, and the capital elasticity of 0.41 based on the regression shown in Table 6 was applied[44].

$$Y = AK^{\alpha}L^{(1-\alpha)} \quad (8)$$

Table 8 shows the results of North Korea's growth accounting from 1956 to 2018. Looking at it by period, North Korea's GDP growth rate from 1956 to 1969 was 7.0%, which was a period of rapid growth. During this period, the contribution of North Korea's labour input and capital input growth were 2.6% points and 3.4% points, respectively. In other words, it can be seen that the high economic growth rate in North Korea at that time was due to the enormous capital investment made in the early stages of economic growth. However, in the 1970s ~ 1980s, North Korea's economic growth rate plunged to 4.2% points compared to the 1950s ~ 1960s; both labour input and capital input growth rates fell significantly compared to the previous period, and above all, it is noted that total factor productivity turned negative. Despite the increase in labour and capital input, the decrease in total factor productivity and the resulting slowdown in economic growth suggest that the inefficiency of North Korea's socialist economic system had already intensified in the 1970s ~ 1980s. In the 1990s, when North Korea's economic level deteriorated enormosly, the economic growth rate seemed to have plunged due to a decrease in capital input and a decrease in total factor productivity caused by deepening inefficiency inherent in the socialist system. On the other hand, since 2000, the growth rate of capital input improved significantly compared to the 1990s, and while the growth rate of labour input remained at a low level, productivity still did not improved, maintaining a low growth trend. More specifically, looking at the situation until 2016, before high-intensity sanctions against North Korea were implemented, the contribution of labour and capital input growth was maintained at 0.6 ~ 0.9% points and 0.8 ~ 1.0%, respectively, contributing to positive GDP growth. However, the situation where the input growth rate of production factors remained at a low level and productivity growth continued to sustain a negative sign (2000 ~ 2009, -0.4%; 2010 ~ 2016, -0.8%) led to a chronic low growth state. Since 2017, when sanctions against North Korea began to be greatly tightened, the contribution of both labour input and capital input growth has fallen by half; the growth rate of total factor productivity has reached a low of -4.8%, and as a result, the annual economic growth rate decreased significantly to -3.9%.

Overall, North Korea was able to achieve input-led growth based on mobilization of labour and increased capital input in the 1950s ~ 1960s, but since then, total factor productivity continued to decrease, and North Korea's economic growth rate seems to have slowed or declined. The results in this study are in line with the study of Kim et al. (2007), who pointed out that the low level of total factor productivity that lasted for a long time was a major cause of the North Korean economic downturn.[45] In addition, the economic structure of North Korea, which can be observed through the

[44] Bergson(1989) assumed the capital elasticity of the output to be 0.325 for estimating total factor productivity of the Soviet Union, and most North Korean studies assume the capital income distribution rate at 0.35- 0.45. For example, Cho(2013) analyzed with regression equation and found that the labour income share for the period 1965 ~ 2012 was estimated to be 0.605, and Choi and St. Brown (2015) used 2/3 as labour income share. Shin and Kim(2018) borrowed the result that Kim et al.(2016) applied the labour income share in South Korea to 0.63 in 2016. Kim(2002) assumed capital elasticity as 0.35, and Kim et al. (2007) estimated that the common capital elasticity of the Soviet Union and North Korea was 0.27 based on the Cobb-Douglas production function. On the other hand, when we look at countries in transition, capital elasticity is somewhat high. For example, Cho et al. (2017) estimated that South Korea's labour income share was 0.68, and the share in four Eastern European countries in transition, including the Czech Republic, Estonia, Hungary, and Slovakia, was 0.54, 14 percentage points lower than that of South Korea. Ezaki and Sun (1999) analyzed growth accounting at the local level in China, and that the labour income share was estimated to be 0.52. As discussed earlier, in this study, as a result of regression analysis of the period 1955 to 2018, the capital elasticity of the calculation was estimated to be 0.41, and it was not so different from the result of the existing literature.

[45] Looking at the estimation results of Kim et al. (2007), which decomposed growth factors based on the labour productivity function, North Korea's total factor productivity growth rate from 1954 to 1989 was -0.9% annually. During the same period, the contribution of the capital intensity growth rate was estimated to be 1.2% points,

results in this study, is not much different from the situation in which the former socialist countries[46)] experienced deep inefficiency of their system and they did not leap up from external growth to internal growth.

<Table 8> Results of Growth Accounting for North Korea

(Average Annual Growth Rate, %, %p)

	GDP growth Rate	Contribution to the increase rate of labour input	Contribution to the increase rate of capital input	Total factor productivity growth rate
1956~1969	7.0	2.6	3.4	1.1
1970~1989	2.8	1.7	1.9	-0.8
1990~1999	-3.3	0.9	-0.9	-3.3
2000~2009	1.3	0.6	1.0	-0.4
2010~2018	-0.2	0.8	0.7	-1.7
('10~'16)	0.9	0.9	0.8	-0.8
('17~'18)	-3.9	0.4	0.5	-4.8

4. Possible Theoretical Explanation on Economic Growth Paths in North Korea

Through the capital stock estimates in this study, a growth model suitable for North Korea can be applied to explain the uncertain economic growth process of North Korea, such as the severe economic crisis in the 1990s. More specifically, the poverty trap model, which was addressed by Leontief (1941), Harrod (1939), Domar (1946), and Barro and Sala-i-Martin (1995), is applied.

As explained in Barro and Sala-i-Martin (1995), economic growth models such as the Harrod-Domar model based on the Leontief (1941) production function are expected to help explain the growth of the North Korean economy in the trap of poverty. Pyo (2013) discussed capital stock estimation methods for emerging economies and transition economies where the capital stock cannot be estimated by the PIM due to lack of long series of investments, along with estimating initial capital stocks. The proposed model considered the aggregate Leontief or fixed coefficient production function as a more appropriate production function than the Cobb-Douglas production function tried in Dadkhah and Zahedi (1986). This is because in emerging and transitional economies, capital input or labour input can be a limiting factor in the production process. In case of North Korea, since it pursues a traditional socialist economy, most production functions are public goods or semi-public goods, and there is little possibility of substitution between capital and labour. Considering these points, the Leontiff production function such as equation (9) used in Harrod (1939) and Domar (1946) seems more suitable.

$$Y = F(K, L) \qquad (9)$$

---

which consequently led to increase the labour productivity growth rate by 0.3%. This study showed somewhat different results especially for the role of capital input growth. In this paper, North Korea's annual average labour productivity growth rate in 1956 ~ 1989 was 1.1%, and the contribution of the capital intensity growth rate was 0.9% points, while total factor productivity growth rate played a role as +0.16% points. The main reason for this difference is that Kim et al. (2007) estimated capital stock growth to be much higher than that in this paper due to calculation errors; the resulting higher capital input growth affected the greater reduction in the rate of change in total factor productivity in the situation where the growth rate of labour productivity decreases.

46 Kim (2017) explained that while the UK's annual total factor productivity was 1.6% from 1950 to 1990, the Soviet Union's annual average total factor productivity was only 0.2% during the same period, which was only 12.5% of the UK, which was a major factor in the decline in growth rate. Bergson (1987) verified that as of 1975, socialist countries in Eastern Europe were inefficient by 25 ~ 34% than advanced countries under the market economy.

$$=\min(AK, BL)$$

Here, A, B: Positive constants

Y_t: Prodcuction at time t

K_t: Capital stock at tiem t

L_t: Labour input in time t

The assumption that there is no substitution between capital and labour assumed in the Leontiff production function led Harrod and Domar to predict that the capitalist economy could have unintended consequences of a continuous increase in labour input or idle capital (Barro and Sala-i-Martin, 1995). In the case of North Korea, it can be said that idle capital continues to increase during the period of Arduous March in the mid-1990s.

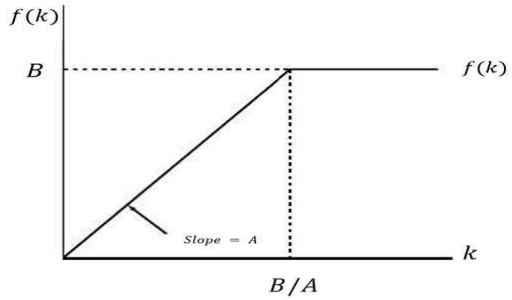
Since the ratio of input elements is fixed in the Leontiff production function, all capital and labour can be in use if AK=BL. However, if AK>BL, then (B/A)L of capital is in use and the other element is idle, and vice versa, if AK<BL is in use, then (A/B)K of labour is in use and the other element is idle.

In order to obtain per capita output, if both sides of Equation (9) are divided by L, Equation (10) is derived.

$$y = \min(Ak, B) \qquad (10)$$

In Figure 9, in case of k<B/A, capital is fully employed and y=Ak. In addition, for k>B/A, the amount of capital employed is fixed, and Y is obtained by multiplication of labour (L) and B (i.e., y=B). When capital per capita (k) approaches infinity, the marginal product of capital, f'(.), approaches 0. As noted in Barro and Sala-i-Martin, the important inada conditions were met, but the production function did not attain endogenous steady-state growth.

<Figure 9> The Leontief Production Function on Per Capita Capital



Sources: Barro and Sala-i-Martin (1995, p.47)

The following equation (11) is established from the equation that net investment (ΔK) excludes depreciation (δK) from total investment (I), and savings with a constant savings rate(sF) is equal to total investment.

$$\Delta K = I - \delta K = sF(K, L) - \delta K \qquad (11)$$

Assuming that the population growth rate is given as constant exogenously ($\Delta L/L = n$) and dividing both sides of Equation (11) by L, Equation (12) is derived.

$$\triangle K/L = sf(k) - \delta k \quad (12)$$

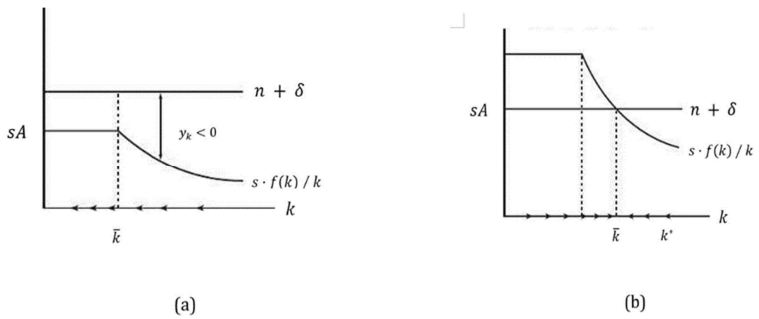
$$\triangle k = d(K/L)/dt = \triangle K/L - nk = sf(k) - (n+\delta)k \quad (13)$$

In case both sides of Equation (13) are divided by k and Equation (10) is substituted, the increase rate of k can be induced as shown in Equation (14).

$$\gamma k = \triangle k/k = sf(k)/k - (n+\delta) = s(\min(Ak, B))/k - (n+\delta) \quad (14)$$

As detailed in Barro and Sala-i-Martin (1995), Figure 10 shows two cases. In case of (a), the savings rate is low so that it becomes $sA < (n+\delta)$, and the growth rate of capital per capita (k) is negative (-) for all ks. In the case of (b), the savings rate is high enough so that k increases infinitely and $s(\min(Ak,B)) / k-(n+\delta)$ approaches zero. This curve eventually intersects the $(n+\delta)$ line at $k^*>B/A$. If an economy is the same as the North Korean economy that started at $k(0)<k^*$ in the early 1950s, the growth rate γk of per capita capital will decrease until it approaches zero at $k=k^*$. Since $k^*>B/A$, idle capital exists as a characteristic of a steady-state economy, but there are no unemployed people. Since k is constant in a steady state, the amount of capital (K) increases along with labour (L), which increases at the rate of increase of n. Since the amount of capital (machine) used is constant, the quantity of idle capital (machine) increases at the rate of increase of n. This state explains the situation of the North Korean economy in the early and mid-1990s, just before the period of Arduous March began.

<Figure 10> The Harrod–Domar model



Sources: Barro and Sala-i-Martin (1995, p.48)

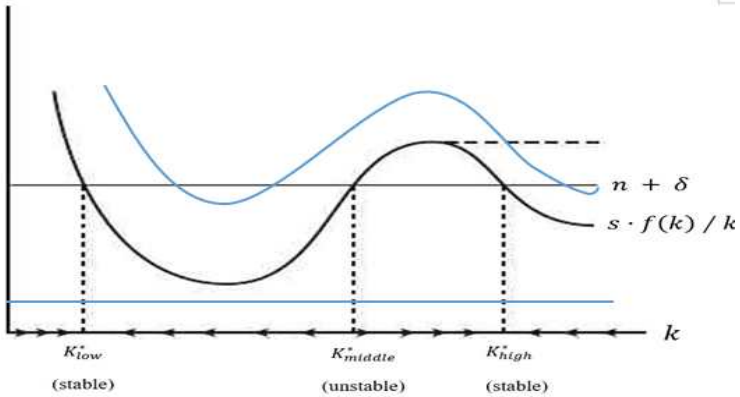
The Harro-Domar growth model economy faces two unintended consequences: a continuous increase in unemployment, or a continuous increase in idle capital (Barro and Sala-i-Martin, 1995). This is because the only way for an economy to reach a full-employment steady state is if the savings rate (sA) matches the sum of the population growth rate (n) and the depreciation rate (δ) (i.e. $sA = n+\delta$). In addition, since all of these variables are given exogenously, the equation may not be established. Amid a continuous increase in unemployment or a continuous increase in idle capital, the North Korean economy is feared to fall into the latter. This is because after falling into the poverty trap in the mid-1990s, it focused on militarization in all socioeconomic aspects.

Barro and Sala-i-Martin (1995) describes the Harrod-Domar model related to the poverty trap. In the early part of Figure 11 where k^* is low, it shows a decreasing return to scale, and this causes the economy of underdeveloped countries to focus on industries such as agriculture and mining, as in the case of North Korea in the 1950s ~ 1960s. As the economy develops, it typically focuses on industry

and service industries, and in the case of North Korea, it is highly likely that it focused on the capital goods industry specialized in military facilities and goods under the slogan of self-reliance. These industries may have an increasing return to scale, but in the case of North Korea, it did not take enough profits from the division of labour and learning effects. This is, expectedly, caused by a situation in which the export market of North Korean military capital goods is limited. In the end, these profits were inevitably depleted, and it is believed that they experienced a decreasing return to scale again. Since the full-employment steady state of k^{*low} is stable, countries whose capital per capita (k) is lower than $k^{*middle}$ will stay in the poverty trap. In case a country such as North Korea starts with a state of $k>k^{*middle}$, its capital can converge to a long-run level of per capita capital (k^{*high}). If the return on capital remains constant at the high level of capital per capita (k), the country's capital per capita (k) will converge at a positive long-term growth rate, as indicated by the dotted line in Figure 11.

As discussed in detail in Barro and Sala-i-Martin (1995), these results suggest that advanced countries such as the United States or international organizations such as the World Bank need to support, with a discrete quantity of capital, countries like North Korea which start economic growth at a low level of capital per capita, k^{*low}. This kind of push can lead to a jump of capital from a lower level of capital per capital than $k^{*middle}$, as shown by the curve $sf(k)/k$ in Figure 11, which allows the economy to accumulate a higher per capita capital stock. At this time, in order to escape from the poverty trap, it is observed that only a large amount of sufficient capital support from the outside can increase per capita capital (k) to a higher level than $k^{*middle}$ or endogenous steady-state growth path.

<Figure 11> The Poverty Trap



Source: Barro and Sala-i-Martin (1995, p.50)

Ⅴ. Summary and Implications

This paper estimated North Korea's fixed investment and capital stock over a long period over 1955 to 2018, and analyzed the economic growth of North Korea by using the capital. This study can be said as differentiated in capital stock estimation from existing studies in the following aspects. First, while prior studies estimated only capital stock as a total, this paper estimated it by dividing into construction assets and facilities assets. Through this, the information could be revealed in which assets North Korea heavily invested by period. Second, it was presented transparently how North Korea's fixed investment by asset was calculated. Third, several parameters necessary for estimating capital stock such as initial capital stock or depreciation rate of each asset were proposed. Although the parameters presented in this paper may not be completely accurate, it can be used as a reference material in conducting similar research in the field later. Fourth, the calculation errors of capital stock estimation in prior studies were corrected. For example, Kim (2002) or Kim et al. (2007) estimated capital stock as the following route: calculation of nominal investment → estimation of the nominal capital stock by the PIM; → estimation of the real capital stock by a deflator. However, this paper corrected the route: estimation of the nominal investment → estimation of the real investment by a deflator → estimation of the real capital stock by the PIM → computation of nominal capital stock by reflation through a deflator.

Looking at the estimation process of fixed investment series, this study estimated the series by asset type on the basis of the 1990 prices, and by dividing fixed investment into construction investment, imported capital goods, and domestic capital goods. Construction investment series was linked to cement production, imported capital goods to net import of capital goods, and domestic capital goods to the growth rate of value-added in the heavy and chemical industry, respectively. From the estimation, fixed investments in both construction and facilities assets was observed to increase rapidly until 1989, but plunged in the 1990s hit by an economic crisis and then recovered in the 2000s. As a matter of notice, since 2017, North Korea's fixed investment plunged again, centering on facilities assets due to the adverse effects of economic sanctions against North Korea. The ratio of fixed investment to GDP was estimated to rise from 15.2% in 1956 to 23.3% in 1990 and then fell to 14.0% in 1999, and then recovered, fluctuating around 21% after the mid-2000s.

This study applied the PIM to estimate North Korean capital stock and assumed huge capital loss during the economic crisis of 1990s. The results are largely summarized into the following sixth. First, North Korea’s fixed assets as of 2018 was estimated to be about 3.9 times GDP. The reproducible fixed capital, mainly observed in developed countries, was about three times GDP; the reason why the capital to GDP ratio of North Korea was so high is that the scale of the economy, the denominator, showed small; it may be said that the result was derived because the North Korean economy had not grown well enough. Second, the estimates showed that the construction assets to GDP ratio was 358%, and the facilities assets to GDP ratio was 33% as of 2018. The facilities assets accounted for about 8% of the two assets at the time, which means that the accumulation of facilities assets was significantly sluggish compared to construction assets.[47)] Third, the series of estimates showed that North Korea's fixed assets accumulated rapidly, then decreased after the high point in 1989, and increased steadily again since the 2000s. Fourth, in case of following the assumption of unexpected capital loss in North Korea during 1990s as assumed in this paper, it was found that capital stock per capita as of 2018 was similar to the level of 1990. However, it needs to be confirmed that the assumption is reasonable. Accordingly, the Cobb-Douglas function was introduced to estimate the production function of North Korea, and then capital stock was derived ex post by substituting the labour input and GDP in that function. As a result, estimates of capital stock derived ex post from the production function showed a very similar level and movement with ones based on some assumptions on capital loss during the 1990s. Fifth, the growth accounting was put in place by applying the growth

[47] The proportion of facilities assets to both construction and facilities assets in South Korea averaged 32% between 1970 and 1990. As of 2018, it is shown as 15%.

rate estimates in Cho and Kim(2021) together with capital stock and labour input estimates in this paper; it was found that North Korea achieved an input-led growth in the early stage of economic growth, but since then, its economic growth stagnated, or economic recovery showed a sluggish trend, due to sustained decrease in total factor productivity as a major factor. Sixth, since the economic crisis in the 1990s, the North Korean economy can be interpreted as showing a kind of poverty trap and idle capital; it can be, in the sense, explained as a Harrod-Domar growth model based on the Leontief production function as described in Barro and Sala-i-Martin(1995).

With North Korea's recent ban on imports of capital goods due to high-intensity sanctions, North Korea is expected to have great difficulties in accumulating facilities assets. The contraction in facilities investment might lead to a decrease in the efficiency of existing facilities and a reduction in the factory operation rate, which may impact negatively on the North Korean economy. In addition, as the growth rate of total factor productivity in North Korea continues to decline, it is required to improve the systemic revision toward the direction of promoting productivity, efficiency, and creativity through innovation in ownership structure and enhanced autonomy in operation of companies or farms. In particular, it seems urgent to improve relations with the international community and actively open up to the outside world in order to introduce advanced technology and enough capital held by developed countries. Based on the theoretical analogy and implications of North Korea's economic growth, it is also necessary to establish a multilateral support organization for North Korea's economic opening and cooperation. Examples that may serve as a catalyst for North Korea to escape from the economic distress are as follows: funds of the parties to the six-party talks, development support funds from the World Bank and the Asian Development Bank (ADB), technical support by the International Finance Corporation (IFC), the United Nations Industrial Development Organization (UNIDO), etc. However, in order for the North Korean economy to escape from the vicious cycle of poverty repeatedly due to idle capital, it will be prioritized to shift the North Korean economy from a closed economy to an open economy rather than providing economic aid. Meanwhile, since the 2000s, the North Korean economy experienced spread of marketization by residents, and recently, the principles of the market economy were systematically accepted, such as giving incentives to increase productivity, so it is worth paying attention to how much this change contributes to improving North Korea's productivity and efficiency.

On the other hand, despite this paper’s trial, estimation of capital stock for North Korea should be supplemented in various aspects. First, the estimation results in this paper need to be compared with the microscopic estimation results. For example, for construction assets, if changes in stock are compared with investment in buildings such as houses, factories, schools, and government offices, or with the estimates of build-up of railway, road, power, urban development, etc., their accuracy may be cross-checked. Second, it is necessary to pay more attention to compiling data that can be used as a deflator; it is because capital stock can be measured properly when real investment series are computed with a relevant deflator. In particular, it seems necessary to pay priority attention to how to deflate trade data with consistency. Third more efforts should be put to increasing the accuracy of the quantity information used in estimating the economic growth rate. It should be recognized that quantity information can be used as an important source for estimating investment and capital stocks as well as economic growth in North Korea. Finally, the estimated capital stock in this paper should be understood as a provisional one under progress. It is because the estimates of North Korean economic growth may be incomplete, and this paper uses them as an unavoidable precondition.

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<Appendix>

A1. Estimates of North Korea's Fixed Investment by Asset (valued at 1990 prices)

(Unit: Million KPW)

	Total Fixed Investment	Construction Investment	Facilities Investment
1955	1,955	625	1,330
1956	2,693	1,018	1,675
1957	2,924	1,527	1,397
1958	3,672	2,123	1,549
1959	4,589	3,269	1,319
1960	5,102	3,902	1,200
1961	5,253	3,889	1,363
1962	5,449	4,035	1,414
1963	5,636	4,164	1,472
1964	5,799	4,271	1,528
1965	6,095	4,395	1,699
1966	6,213	4,518	1,695
1967	6,319	4,644	1,675
1968	6,814	4,772	2,042
1969	7,432	4,897	2,535
1970	7,814	5,042	2,772
1971	8,220	5,177	3,043
1972	8,603	5,323	3,279
1973	8,652	5,471	3,181
1974	10,097	5,621	4,476
1975	10,058	5,774	4,284
1976	9,344	5,938	3,406
1977	9,105	6,103	3,002
1978	9,308	6,462	2,846
1979	10,085	6,910	3,175
1980	11,715	8,147	3,568
1981	10,577	7,117	3,460
1982	11,349	7,757	3,593
1983	11,719	8,049	3,670
1984	12,834	9,055	3,779
1985	12,197	8,285	3,912
1986	12,854	9,079	3,775
1987	13,271	9,418	3,854
1988	14,123	10,142	3,981
1989	14,008	9,865	4,143
1990	14,127	10,437	3,690
1991	12,743	9,412	3,331
1992	12,389	9,716	2,673
1993	11,220	8,753	2,467
1994	8,665	6,369	2,296
1995	8,647	6,442	2,204

1996	7,802	5,940	1,862
1997	6,902	5,448	1,454
1998	5,623	4,343	1,280
1999	7,110	5,568	1,541
2000	7,917	6,348	1,569
2001	8,382	6,620	1,762
2002	9,447	7,672	1,774
2003	10,363	8,476	1,887
2004	11,073	9,243	1,831
2005	11,943	9,925	2,018
2006	11,265	9,192	2,073
2007	10,903	8,948	1,955
2008	10,932	8,655	2,276
2009	10,708	8,297	2,411
2010	10,715	8,262	2,453
2011	10,860	8,211	2,650
2012	10,918	8,174	2,745
2013	11,146	8,269	2,877
2014	11,991	8,778	3,213
2015	12,347	9,537	2,810
2016	12,587	9,766	2,821
2017	11,479	9,214	2,266
2018	10,412	9,085	1,327

Note: The real investment series is estimated by linking to growth rate of value-added (base year=1990) in heavy and chemical industry for facilities investment, and by linking to growth rate of value-added in construction industry for construction investment. The growth rate of industries' value-added before 1990 comes from Cho and Kim (2021).

A2. Estimates of North Korea's Capital Stock by Asset (valued at 1990 prices)

(Unit: Million KPW)

	Total Fixed Capital Stock	Construction Capital Stock	Facilities Capital Stock
1955	20,278	16,115	4,029
1956	21,633	16,585	5,048
1957	23,210	17,539	5,671
1958	25,400	19,048	6,351
1959	28,361	21,635	6,726
1960	31,698	24,759	6,940
1961	35,043	27,767	7,276
1962	38,434	30,819	7,615
1963	41,860	33,897	7,962
1964	45,294	36,979	8,315
1965	48,861	40,082	8,780
1966	52,380	43,203	9,177
1967	55,848	46,344	9,503
1968	59,636	49,508	10,128
1969	63,819	52,690	11,129
1970	68,125	55,910	12,215
1971	72,564	59,156	13,408
1972	77,100	62,440	14,660
1973	81,412	65,760	15,652
1974	86,836	69,118	17,719
1975	91,843	72,515	19,328
1976	95,863	75,963	19,900
1977	99,478	79,458	20,020
1978	103,169	83,191	19,977
1979	107,489	87,242	20,248
1980	113,223	92,375	20,848
1981	117,593	96,326	21,267
1982	122,529	100,776	21,753
1983	127,612	105,367	22,245
1984	133,569	110,795	22,774
1985	138,642	115,287	23,355
1986	144,141	120,412	23,729
1987	149,828	125,701	24,127
1988	156,117	131,527	24,590
1989	162,031	136,889	25,142
1990	161,205	136,944	24,261
1991	159,005	135,832	23,172
1992	152,724	131,600	21,124
1993	149,927	130,166	19,761
1994	148,357	129,477	18,880
1995	143,742	126,064	17,678
1996	140,179	123,659	16,520

1997	131,907	117,184	14,724
1998	130,382	116,563	13,819
1999	131,588	118,193	13,395
2000	133,590	120,536	13,054
2001	136,008	123,069	12,939
2002	139,404	126,553	12,851
2003	143,592	130,713	12,879
2004	148,342	135,490	12,852
2005	153,783	140,780	13,003
2006	158,359	145,174	13,185
2007	162,416	149,183	13,233
2008	166,346	152,773	13,573
2009	169,885	155,892	13,993
2010	173,269	158,873	14,396
2011	176,634	161,706	14,928
2012	179,885	164,408	15,477
2013	183,191	167,116	16,075
2014	187,141	170,235	16,906
2015	191,246	173,996	17,250
2016	195,417	177,859	17,557
2017	198,357	181,052	17,305
2018	200,224	184,012	16,212

A3. Labour-Age Population and Labour Force Restructuring in North Korea

Representative data, producing North Korea's total population and population estimates by age from the 1950s to the present, are those of Statistics Korea and the “World Population Prospects” of the United Nations. Statistics Korea supplies North Korea's total population and population aged 15 or older every five years from 1965 to 1990, and annual figures since 1993. The United Nations present data on North Korea's total population and population estimates by age from 1950 to the present. Meanwhile, North Korea itself presented total population, population by age, and labour force, etc., through the 1993 and 2008 census, which is used as an official data for North Korea and a reference point for population estimates in Statistics Korea and the United Nations.

What is noteworthy in the 1993 and 2008 census of North Korea is that in the 1993 data, the total population by city and province and the total population by age are not consistent, whereas in the 2008 data, they are consistent. More specifically, North Korea's total population by region in 1993 was 21.21 million, while the total population by age was 20.52 million, showing a difference of about 0.69 million. In response, the existing literature suggested the possibility that soldiers would not be included in North Korea's age-specific population (Eberstadat and Banister, 1992; Kim, 2002). On the other hand, the 2008 Population Census stipulates that the sum of the population by region and age is the same and includes residents and soldiers living in group facilities.[48)] Statistics Korea's estimate of North Korea's population states that soldiers were excluded, and its estimate is smaller compared to the North's population totals in 1993 and 2008, which included the number of soldiers. Meanwhile, it is not clear whether the number of soldiers is included in the UN's global population prospects, but it is not likely that soldiers will be excluded as it is larger than total population announced by North Korea's official statistics. This shows that it is necessary to pay attention to whether soldiers are included in North Korea's population estimate, and they should be consistently reflected in total population.

<Table A3-1> Features of North Korea’s Population Data

	DPRK Population Census		Statistics Korea (1965~2017)	UN World Population Prospects (1950~2018)
	1993	2008		
Total Population (thousand)	21,210	23,350	21,103 (in 1993) 23,934 (in 2008)	21,266 (in 1993) 24,310 (in 2008)
Soldiers	Yes by region But not by age	Yes	No	Yes but estimates
Regarding Ages	By Age (15-year-old population is identified)	By Age (15-year-old population is identified)	Until 2002: from 15 year old From 2003: from 16 year old	by 5-year age (Population of 15 and older are available)

Another important component in estimating North Korea's labour force is the definition of the labour-age population. In international standards, the labour-age population refers to the population aged 15 or older, of which the proportion of the labour force participating in economic activities is the participation rate in economic activities. However, North Korea has a labour age of 16 under Articles

[48] However, Lee(2011) raised the possibility that North Korea's population aged 25 ~ 34 was reported less than the actual population. In other words, in the case of the 2008 population census, it was noted that the proportion of male soldiers to the male population in the conscription age group differs compared to the service period of the North Korean military (10 years). As a result of adjusting the ratio of military call-up by age for conscripted age in consideration of the service period, the number of North Korean soldiers was estimated to be 1.16 million.

31 and 15 of the Socialist Constitution and the Labour Law, which are due to compulsory education until the age of 16 under the 11-year compulsory education system, which took effect in 1975 (Wang and Yin, 2000). Accordingly, the labour-age population in North Korea, provided by Statistics Korea, is excluded from the number of soldiers; since 2003, it is specified as a population over 16 years old except for soldiers. However, in the data before 2003 by Statistics Korea, since the labour-age population is the population aged 15 or older, it is necessary to unify the concept to the population aged 16 or older by deducting the population aged 15.

Considering the above discussion, this study defined the labour force of North Korea as the population aged 16 or older excluding soldiers. In addition, data from Statistics Korea, which presents both the labour-age population and the economically active population, were used as basic data. However, data from Statistics Korea showed that before 2003, the labour-age population was defined as the population aged 15 or older, so the population aged 15 or older must be deducted. In the 1993 North Korean Population Census, the 15-year-old population was counted as 323.8,000, so the time series was estimated by applying the increase or decrease rate of the 15-year-old population[49)] estimated based on the UN global population prospects. Meanwhile, from 1965 ~ 1990, the labour-age population by Statistics Korea was provided in 5-year units (1965, 1970, 1975, 1980, and 1985), so the intermediate year was linearly interpolated assuming that the annual growth rate was the same. Since there was no labour-age population by Statistics Korea in 1955 ~1964, after estimating the time series of the population excluding the number of soldiers[50)] from the 16 or older population in the UN data, the increase rate of this time series was applied to the labour-age population of Statistics Korea to estimate the past time series before 1965. Through this process, this paper was able to estimate the labour-age population of North Korea from 1955 ~ 2018.

Meanwhile, this paper used North Korea's economically active population provided by Statistics Korea as the North Korea's labour force under the assumption that the latter would not be significantly different from the former because North Korea's central planning authorities would have implemented a full employment policy in the past. However, Statistics Korea's economically active population are presented every five years for the 1965 ~ 1990 period. This paper was linearly interpolated under the assumption that the annual growth rate was the same for the intermediate year. Meanwhile, the labour force from 1955 ~ 1964 was calculated by multiplying the labour-age population by the participation rate in economic activities. Based on Wang and Yin (2000)'s 1960 economic activity participation rate of 60.3% and the 1965 economic activity participation rate of 62.8% by Statistics Korea, it was assumed that the economic activity participation rate during 1955 ~ 1964 was the same as the annual change in the corresponding participation rate during 1960 ~ 1965. The economically active population for the period was estimated by multiplying this economically active participation rate by labour-age population during 1955 ~ 1964 estimated earlier. In addition, in the case of 2003 ~ 2009, the economically active population showed severe fluctuations. Therefore, it was re-estimated without using it as it is. In other words, as of 2002 and 2010, the economic activity participation rate was linearly interpolated and estimated, and then the economically active population was recalculated.

[49] In the UN World Population Prospects, the population aged 10 ~ 14 and the population aged 15 ~ 19 are provided, so the average between (the population aged 10 ~14/5) years and (the population aged 15 ~ 19 years/5) were assumed to be the population aged 15 years. Calculated in this way, the population aged 15 years in 1993 was 364,000, which is not much different from the 323,800 surveyed in the North Korea's census.

[50] In 1955 ~ 1961, the data from the Institute for Far Eastern Studies (1980) were used for the number of North Korean soldiers, and in 1962 ~ 1964, the data from Yang et al.(2011) were used.