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Analyzing the Business and Environmental Implications of Agricultural Policy Changes in North Korea

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Abstract

The agricultural policy of Kim Jong-un's regime inherits the economic reform policy of the Kim Jong-Il period, which expands the autonomy of production and allows the market to dispose of products. The formation of markets represents an important factor in the business environment, as it indicates the establishment of fundamental conditions for management. However, major crops are still mainly managed by the state, and the government implements agricultural policies, such as emphasizing "Juche Farming." This study analyzed the impact of transition economic policies during the Kim Jong-un period on agricultural production using variability. Production variabilities increased for minor grain crops compared to previous years, but those of major grain (rice and maize) and horticultural crops did not change significantly. Even the production quantity of horticultural crops decreased, which is different from previous predicts that the expansion of the North Korean market would increase the consumption power of North Koreans and promote horticultural crop production. This study underscores the imperative for North Korea to develop policies aimed at stabilizing crop yields in the face of production variability. It proposes the establishment of an agricultural early warning system as a feasible solution to enhance agricultural infrastructure and promote inter-Korean cooperation.

Keywords : North Korea, agriculture production, volatility, economic reform, Kim Jong-Un regime

JEL Classification Code : P32, O43, P48

1. Introduction

During the mid-1990s, North Korea experienced its worst food shortage period ("the Arduous March"), and despite its economic recovery in the 2000s, the country's food shortage has not been resolved. In 2009, the country produced only 41.07 million tons of grain, which fell 700,000 tons short of the minimum requirement of 480g per day. Even after more than a decade, the situation has not significantly improved, with the grain shortage in 2019 reaching 371,000 tons (based on the author's calculation, Table 3).

The primary cause of the food shortage is the low food production, but the weak food supply chain in the country has also worsened the problem. The COVID-19 pandemic and subsequent border lockdowns have significantly

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affected North Korea's grain imports, which fell to 43% of the average year, and fertilizer to 4.2% of the average year in the first half of 2020. Consequently, the Food and Agriculture Organization of the United Nations (FAO) reported that 10.1 million people faced food insecurity in North Korea in 2020 (FAO, August 14, 2020). Furthermore, extreme weather conditions caused by global climate change have negatively affected North Korea's food production (Kim & Lee, 2020; The Rural Development Administration). In 2021, the North Korean authorities acknowledged that the country had suffered severe damage to agricultural production and people's livelihoods due to natural disasters such as floods, droughts, typhoons, and hot temperatures (DPRK, 2021).

The North Korean authorities have not ignored the food shortage issue in the country. Each of the three North Korean regimes that have been hereditary (Kim Il-sung to Kim Jong-Il, and to Kim Jong-Un) since the Great Famine implemented various reform policies to increase food production and achieve food security, especially in response to the increasing climate crisis (Em, 2024). The policies have affected North Korea's traditional socialist economic system and are an essential subject of North Korean economic research (Kim, 2017).

However, most of the research has focused on qualitative research, and quantitative analysis is rare because of the difficulty in obtaining reliable statistical data due to the fundamental limitations of North Korean research. Since the 1960s, the FAO has collected North Korea's agricultural production statistics. Analyzing these statistics can help understand North Korea's economic changes in agriculture caused by policy changes. Therefore, we attempt to analyze the economic policy changes in the three significant periods of the changes and their impacts on agriculture in North Korea: the period of Great Famine (1994 – 2001), the period of economic reformation (2002 – 2011), and the Kim Jong-Un regime (2012 – present).

We specifically analyze the variabilities of agricultural production by incorporating the impacts of policy changes. If production variability increases in a chronic food shortage situation in response to policies, it implies that the uncertainty of the North Korean regime increases and worsens the living conditions of the people. Conversely, if variability is alleviated, even in a chronic food shortage situation, it means that the food supply is stable. Thus, we can find mitigation factors against the food shortage problem by analyzing variability. From these aspects, we use the coefficients of variation to analyze the variabilities of agricultural production in response to agricultural reform measures in North Korea, which can more clearly show the actual performance of the changes caused by the policies.

This study is structured as follows. The first section is introduction. The second section examines the agricultural performance compared to the other sectors of North Korea after Great Famine. The third section discusses North Korea's agricultural production systems and policies that have been taken, and their achievements to see the changes made in the sector. The fourth section summarizes the previous chapters deriving research questions. The fifth section empirically analyzes whether the North Korea's policy changes affect the agricultural production variabilities by using a decomposition approach of the coefficients of variation. The sixth section examines changes in agricultural production patterns during the Kim Jong-un regime. Finally, the last chapter presents the implications and limitations with the conclusion of this study main section of an article should start with an introductory section which provides more details about the paper’s purposes, motivation, research methods, and findings. The introduction should be relatively nontechnical, yet clear enough for an informed reader to understand the manuscript’s contribution.

2. Literature Review

2.1. Half Success of Economic Performances after Great Famine

The North Korea's economy has been stagnant in general since 1994 at the level of the Great Famine period except for some industrial indicators. During the economic reformation period, the population increased by 8.7% compared to the Great Famine period and then rose 5.3% from the previous period during the Kim Jong-Un regime. It reached 24.77 million under Kim Jong-Un's rule, a 14 percent increase over Great Famine. The total length of roads and railways was 26,151 km and 5,287 km in the period., They increased by 11.8% and 2.3% respectively compared to Great Famine period. The electricity, gas, and water industry index grew from 86.8 during Great Famine to 102.3 in Kim Jong-un regime, but the heavy and chemical industry has lagged. Looking at the growth of each factor by period, the country grew more in the economic reformation period (②) than Kim Jong-Un period (③). It means that the growth of the North Korean economy has slowed, and the economic efficiency has declined as well.

Unlike the other sectors, the agricultural sector has been relatively active during the same period. Especially, agricultural production has increased even in the inputs reducing condition. Under Kim Jong-Un’s rule, the agricultural, forestry, and fishery GDP index is 121.6, increasing 28.5% compared to the Great Famine period. Grain production has increased, although vegetable production was decreased. This is noteworthy that the increase was made while major inputs have been reduced.

The rural population as a labor force grew by 7.5% compared to Great Famine period, but the fertilizer production capacity decreased by 19.0% and the arable land also reduced by 3.2%. This implies that land productivity per capita of agriculture has increased after Great Famine (KSTAT from agricultural productivity).

Table 1 Major Economic Indicators of North Korea (1994=100)

Period		Great Famine ①	Economic Reformation ②	Kim Jong-Un Regime ③	Comparison		
					②-①	③-②	③-①
Major Economic Indicators	GDP	91.7	100.4	105.7	8.7	5.3	14.0
	Population	103.3	110.2	115.5	6.9	5.3	12.1
	Total road extension	100.8	108.8	112.6	8.0	3.8	11.8
	Total railroad extension	101.1	102.5	103.4	1.3	1.0	2.3
	Electricity, Gas and Water	86.8	94.4	102.3	7.6	7.9	15.5
	Heavy Chemical Industry	79.9	77.5	74.8	-2.4	-2.7	-5.1
	Agriculture	93.1	109.8	121.6	16.7	11.8	28.5

Note: ① Great Famine (1994~2001) ② The Economic Reform period (2002~2011) ③ Kim Jong-Un's reign (2012~Recent)
Source: calculated by the author using the data from KSTAT and FAO

Table 2 Major Agricultural Indicators of North Korea (1994=100)

Period		Great Famine ①	Economic Reformation ②	Kim Jong-Un Regime ③	Comparison		
					②-①	③-②	③-①
Agricultural Indicators	Agricultural Production	93.1	109.8	121.6	16.7	11.8	28.5
	Grain Production	69.7	84.7	92.8	15.0	8.1	23.1
	Vegetable Production	102.1	106.6	97.9	4.4	-8.7	-4.3
	Rural Population	102.7	108.4	110.2	5.6	1.8	7.5
	Chemical Fertilizer Production Capacity	98.6	82.6	79.6	-16.0	-3.0	-19.0
	Cultivation Area (Stock)	99.0	95.2	95.8	-3.8	0.6	-3.2
	Grain Cultivation Area (Flow)	96.6	97.3	91.2	0.7	-6.2	-5.4
	Vegetable Cultivation Area (Flow)	100.1	103.2	95.0	3.0	-8.2	-5.2

Note: ① Great Famine (1994~2001) ② The Economic Reform period (2002~2011) ③ Kim Jong-Un's reign (2012~Recent)
Source: calculated using the data from KSTAT and FAO

Table 3 Status of the Food Supply in North Korea between 2000 and 2019

Unit: 1,000 metric ton, kg (shortage per person)

Year	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total Supply(A)	5,434	6,234	4,771	-	-	5,729	5,213	5,086	4,655	4,920	4,873	4,839	5,138
Production	3,590	4,537	4,107	-	-	4,676	4,807	4,803	4,512	4,823	4,701	4,558	4,640
Import	647	640	381	365	487	706	370	261	108	95	172	281	498
Foreign Aid	1,197	1,057	283	86	88	347	36	22	35	1	-	-	-
Minimum Requirement(B)	4,959	5,147	5,256	5,284	5,310	5,336	5,362	5,387	5,413	5,439	5,464	5,490	5,516
Gap (A-B)	+475	+1,088	-485	-	-	+393	-149	-301	-758	-519	-591	-651	-378
Shortage per person	+21	+46	-20	-	-	+16	-6	-12	-31	-21	-24	-26	-15

Note: An investigation of the food shortage situations in North Korea using a food balance sheet reveals poor food supply and demand conditions. As the North Korean government does not publish official food supply and demand statistics, the food supply could be estimated using the following methods. Total supply is the sum of production, import, aid, and production based on grain production statistics from Korea's Rural Development Administration (Statistics Office). The statistics were not released in 2010 and 2011. The number of imports is based on UN COMTRADE (as of December 2020), including rice, corn, wheat (including wheat flour), soybeans, potatoes, oats, buckwheat, sorghum, and rye. The data after 2017 have not been released. The minimum requirement was about 5.3 million tons in 2011. It was estimated at 480g per day (about 174 kg per year) of actual food consumption per capita in North Korea.
Source: calculated using KSTAT, UN COMTRADE

However, there has been still a food shortage despite the growth in agricultural production. In 2012, North Korea's total food supply was 57.29 million tons, which barely exceeded the minimum requirement of 3.93 million tons. But it has fallen far short of the minimum requirement after 2013 making the shortage up to 1.49 to 7.58 million tons every year. Domestic production, imports or aid must be increased to solve the food shortage problem on the supply side. However, it is not easy to import food from abroad as UN sanctions against North Korea are in effect and Corona 19 is spreading around the world and in North Korea. Moreover, domestic production has not improved significantly since 2012, stagnating between 45 and 48 million tons. As a result, chronic food shortage has been continuing while the annual per capita food shortage was estimated to reach about 31 kg (see Table 3 below).

Agriculture has made some positive performances compared to the other sectors that show no significant improvements since the Great Famine period but declined the growth rates. However, food shortage problems have remained despite the relatively positive agricultural performances. In other word, the agricultural reform trials have been 'half-success'. The institutional inefficiency of the North Korean (or socialist) economic system is presented as one of the leading causes of the great famine in the country in the 1990s and following sustained food shortages with the other several aspects (Noland et al., 2002; Kim, 2017). Macroeconomic coordination failure (Kim, 1997), continuous occurrence of severe natural disasters (FAO, May 13, 1996), a decline in import/aid due to the collapse or transition of past socialist countries (Lim, 1998), lack of social infrastructure (Lee, 2016), and the protection of the Kim Il-sung-centered dictatorship (Bae, 2011). If we investigate the North Korea's agricultural policy changes after the famine, we could figure out why the North Korea's efforts achieved only half success.

2.2. North Korea's Economic Reform After Great Famine and its Impacts on Agriculture

2.2.1. Traditional Agricultural Production System

North Korea's agricultural sector operates under a socialist management system. In 1953, the country established a cooperative and state-owned farming system, requiring all farm households to join cooperatives to form a collective agricultural system. In 1964, the country announced the 'Thesis on Socialist Rural Issues,' which completed the labor-intensive collective farm system. North Korea then reorganized the agricultural management system, promoting the 'Juche farming method' by stipulating detailed and specific farming methods to fully realize the central extension and management system (Kwon et al., 2004; Lim & Kang, 2000).

The agricultural management system in North Korea is divided into a central authority and collective farms. The central authority oversees planning, while the collective farms are the implementation units that perform farming plans through collective farming. Agricultural planning occurs in three stages: preliminary planning, control planning, and national economic planning. The Agricultural Commission, an institution under the Ministry of Agriculture, carries out preliminary planning. The preliminary plan is then delivered to the collective farm units through the district collective farm management committees. The collective farms decide the preliminary production plan and the estimated budget by adjusting the plan according to their situations. The modified plans and budgets at the cooperative levels are collected, revised, and supplemented by the agricultural committees at the district and provincial levels. They are then finalized as a draft national agricultural production plan every year. This draft plan is called the control plan, which is delivered to the collective farms through the provinces and districts as an annual production and financial plan. Based on the control plan, collective farms establish crop and variety arrangement plans and agricultural material supply plans and revise them in consultation with working groups and sub-production teams. After being reviewed by the management committee, the draft is approved by the members' general meeting. The proposed plans are finally confirmed as national plans and have become legally effective. However, the central authority controls detailed tasks such as crops, varieties, and production methods that must be performed even at the minimum production unit levels with limited autonomy, especially for main food crops such as rice for security reasons (Chang et al., 2010).

In addition to the controlled farm management system, North Korea has also been promoting the Juche farming method since the 1970s to solve the food shortage problem (Yoon, 2020). This intensive farming method emphasizes timely cropping for efficient use of land, planting suitable crops for the right locations, and high-density cultivation. Furthermore, a large amount of chemical fertilizer is used, and high-yielding crops, mainly staple cereal crops such as rice and maize, are primarily planted to increase productivity per unit area. Mountains are cut to create terraced farmland to expand agricultural lands. The Juche farming method also specifies farming methods in detail at the national standard for individual crops, including rice, vegetables, corn, fruit, mulberry, tobacco, potato, soybean, silkworm, cotton, rapeseed, perilla, red bean, peanut, buckwheat, flaxseed, sorghum, livestock, sesame, sunflower, and beans. For example, the production process for rice, such as cultivar arrangement, seed treatment, germination, disinfection, hair growth, farming technology, fertilizer cycle, paddy water cycle, pest prevention, and harvest areas,

is stipulated. Non-compliance with the national standard results in legal sanctions (Suh & Nam, 2017).

2.2.2. Market Economy Adoption Attempts during Economic Reformations

The traditional agricultural system of the country lacked autonomy, which made it difficult to respond to different situations and environments. This rigidity resulted in a decline in production during the Great Famine. To alleviate this problem, the North Korean government implemented policies to introduce more flexibility in agriculture during the economic reformation period of the 2000s. In 2002, Kim Jong-Il, led by Park Bong-Ju, released the 7.1 Economic Improvement Measures to promote economic and agricultural reforms, including market revitalization and operational improvement of collective farms (Kwak & Moon, 2017).

The North Korean authorities introduced various policies to revitalize the market and provide regulatory guidelines to support it. During the food crisis of the 1990s, the public distribution system failed, and the general population needed livelihoods. As a result, the unofficial farmers' markets, also known as "Jangmadang," were created spontaneously. However, the government did not have control over them. To regulate the market system, the government attempted to strengthen the state-run store networks and control the farmers' and unofficial markets at the early stage of the 7.1 measures. A general market was opened in Pyongyang at the end of March 2003, with plans to spread throughout North Korea. However, the introduction of the market economy failed due to a lack of necessities such as rice and vegetables. Therefore, from December 2003, agricultural and industrial products were allowed to be traded in Jangmadang again, and the market in North Korea expanded despite the authority's regulations. After October 2007, the government attempted to regulate the market again by cracking down on illegal transactions and controlling the commercial trade (distribution) sector. In 2009, the North Korean authorities attempted more robust measures to regulate the market during the currency reform period. These measures included returning the general market to a 10-day market and restricting trade items to agricultural and local products. However, due to setbacks in product distribution and soaring prices throughout the country, the related regulatory policies were lifted around February 2010. As a result, the market in North Korea rapidly expanded.

In addition to revitalizing the market economy, the reforms during the Kim Jong-Il period created demands for economic reform for farmers (Jung, 2023). The measures in the agricultural production sector were mainly focused on enhancing agricultural efficiency by reducing farming scale in collective farms and granting autonomy to farmers to incentivize them to produce more. The North Korean authorities started implementing measures to reduce the sizes of collective farms before the 7.1 measures. The number of subgroup members in collective farms was reduced from 10-25 to 7-8 people. Further pivot policies were carried out in regions such as Sinuiju and Onseong to reduce the number to 4-5 per subgroup.

The policies focused not only on reducing farming sizes but also on motivating farmers. Production targets of the subgroups were realistically set, and the incentives for excess production were expanded. Surplus production from sub-teams and products from individual farms were allowed to be sold in general markets. The profits of collective farms were distributed differentially between sub-teams according to performances instead of even distribution. After-work hour activities of the collective farms were guaranteed, and the permitted sizes of individual vegetable gardens increased from 100 square meters (30 pyeong) to 1,320 square meters (400 pyeong).

However, despite various attempts to introduce market economy principles in the country, the agricultural reform measures were not very successful due to the inherent ideological (Juche) and institutional limitations. These measures were introduced only on a trial basis and in limited parts of the economy without reforming the existing political ideology or government systems. As a result, the traditional management system that included all the elements of the planned economy, such as socialist cooperation ideology and goal-setting implementation, remained largely unchanged. Therefore, the market economy elements were only allowed within the existing frameworks of collectivist and planned economies, resulting in limited reformation policies through partial acceptance of market economic elements and loosening of control, as evaluated by the 7.1 measure and subsequent reform measures (Leem, 2007).

2.2.3. Agricultural Policies during Kim Jong-Un's Reign

Following partially successful attempts to introduce market elements (RFA. 2018.02.03.; Hong et al., 2016), the Kim Jong-Un regime sought to strengthen the successes of previous regimes and maintain traditions while developing its own approach. After taking power at the end of 2011, Kim Jong-Un implemented two significant measures that significantly impacted agricultural policy: the "our-style economic management method" (hereafter referred to as "Method") and the "Five-Year Economic Development Strategy" (hereafter referred to as "Strategy").

The North Korean authorities announced the "Method" in April 2012, which allowed for greater autonomy and diversity in agriculture, as well as other sectors (Kim, 2014). Measures were taken to strengthen the management system of cooperative farms, expanding their rights to farm

planning, organization, financial management, and sales. The farmer responsibility system was also introduced, allowing families to farm within the cooperative farm to increase productivity (Kim, 2019). The "Strategy," announced in May 2016, emphasized the agriculture-fishery-light industry as one of the main sectors for revitalizing the economy (KOTRA, 2017). The strategy provided clear guidelines for disposing of agricultural products, specifying that the remaining products, except for the amount dedicated to the state, should be sold to other institutions and businesses. This allowed farms to purchase necessary supplies for production and management activities (Peter & Han, 2019). The Kim Jong-un regime demonstrated a keen interest in the agricultural sector through these policies, aiming to increase food self-sufficiency (Hong, 2012).

However, the regime did not transition the economy and agriculture sector from socialist to a full market system (Kim, 1997), focusing instead on gradually changing the agricultural system within the socialist framework. The North Korean authorities revised the "Farm Act" four times between 2012 and 2015, primarily focusing on the production sector, such as the right to dispose of surplus products and improving distribution to farms and the state's grain purchase method (Korea Ministry of Government Legislation, 2019). These measures successfully set the direction for agricultural reforms (Kwon et al., 2019).

Changes in agricultural technology policies were also noted. The Labor Party of Korea presented significant tasks for the agricultural and livestock industry during the 7th (2016) Congress, emphasizing the scientification of agricultural production activities to strengthen the self-reliant national economy (Kim, 2015). Scientific farming has been continuously emphasized, stressing the rationalization of agricultural production activities such as seed production by regions and varieties, crop arrangements based on geographical characteristics and natural climatic conditions, and establishing a circulation system (Kim, 2021). Multi-cropping has recently been emphasized as a way to increase grain yield per unit area and increase agricultural production in limited arable land. Kim Jong-Un ordered farmers to adopt two- and three-fold farming methods and instructed them to scientifically cultivate various crops (Rodong Sinmun, March 13, 2019).

3. Derivation of Research Question

3.1. Research Question

Overall, North Korea has been pursuing a self-reliant national economy and striving to increase agricultural production by reforming the centralized agricultural management system. During Kim Jong-Il's reign, the authorities granted more autonomy in the production process and expanded rights to dispose of products to restore degraded agricultural productivity. Under Kim Jong-Un's leadership, scientific production was emphasized while past policies were accommodated and flexible crop outputs encouraged. This ongoing sequence of "problem occurrence-reform attempt-reform settlement and change" coexists with the Juche farming method and autonomous market approaches in North Korea.

This phenomenon presents an interesting research topic, and empirical analysis could have significant economic and policy implications. Currently, there are very few studies on economic changes in North Korea. Economic policy changes may affect production volatilities differently for each crop, and if policy changes have not brought about fundamental changes in agriculture, the pattern of agricultural production could remain the same. Therefore, this study's hypothesis is as follows: if the null hypothesis is accepted, North Korea's policy change will have minimal effects on agricultural production. Conversely, if the alternative hypothesis is accepted, policy changes will affect agricultural production. This study's hypothesis provides an opportunity to verify the performance and challenges of agricultural growth affected by North Korea's economic policy changes.

H_0= *Littles changes in agricultural production patterns are observed by period* ($\mu_0 \approx \mu_1$).

H_1= *Changes in agricultural production patterns are observed by period* ($\mu_0 \neq \mu_1$).

3.2. Methodology

To analyze the variability of North Korea's agricultural production, the coefficient of variation can be estimated using basic statistics. Yields can be calculated from cultivation area statistics, and the level of variation in production (i.e., the coefficient of variation in production) can be obtained using the same data. The coefficient of production variation can then be decomposed into two factors: the yield and the cultivation area effect (also known as the "area effect") (Ha & Kim, 2016). Expressing this as equitation is as follows. In this case, S_t, Q_t and Y_t respectively, represent the production, cultivation area, and yield (productivity) of certain agricultural products in the t period (Reed et al., 2002).

$$S_t = Q_t \times Y_t \quad (1)$$

There are various statistical techniques to measure variability, and among which the coefficient of variation is

a representative technique. The coefficient of variation (CV) is calculated by dividing the standard deviation by the mean (Wilkinson, 1961). CV is widely used in empirical research because of its intuitiveness and convenience (Ahn & Kim, 2008; Ha & Kim, 2016). The coefficient of variation (CV_s^2) of production is obtained in a specific period, Taylor expression can be applied. As a results, the coefficient of variation in output can approximately decompose the cultivated area of coefficients of variation (CV_Q^2), the yield of the coefficients of variation (CV_Y^2) and the correlation coefficient (ρ).

$$CV_S^2 \approx CV_Q^2 + CV_Y^2 + 2\rho CV_Q CV_Y \quad (2)$$

Using Equation (2), the proportion of the contribution of variability in cultivation area and yield to the level of variation in production can be obtained and expressed by Equations (3), (4), and (5) below. In this case, α is the contribution of the variability of the cultivated area to the total production variability, which means the area effect. Furthermore, β is the yield effect. Finally, γ is the correlation effect. The sum of α, β, and γ is 1, if the area and yield effects are uncorrelated γ is 0.

$$\alpha = CV_Q^2 / CV_Q^2 + CV_Y^2 + 2\rho CV_Q CV_Y \quad (3)$$

$$\beta = \frac{CV_Y^2}{CV_Q^2} + CV_Y^2 + 2\rho CV_Q CV_Y \quad (4)$$

$$\gamma = 2\rho CV_Q CV_Y / CV_Q^2 + CV_Y^2 + 2\rho CV_Q CV_Y \quad (5)$$

The coefficients of variation derived from the equation (2) is distributed in the range of 0 to 1 (or 0 to 100%) and can be used to confirm the intensity of the change. (George et al., 2002). However, the value of the coefficient of variation in this study is derived from economic statistics and should be interpreted empirically so that the standards may be different for each study. Therefore, in this study, if the value of the coefficient of variation is less than 0.05, the variability is interpreted as (absolutely) small; if it is between 0.05 and 0.1, it is relatively big; and lastly if it is above 0.5, it is interpreted as (absolutely) large. Meanwhile, α, β, γ explains how much each value contributes to the interpreted level of variation, and the sum of the respective value is 1 (or 100%). For example, supposing γ is 0 and then the sum of α and β will be 1. In such a case, the value for each factor will be 0.5 if the contributions are same, and (1,0) or (0,1) will be if only one factor contributes.

For example, suppose that corn production fluctuates significantly during a period, with a downward trend. During the time, the area does not change but only the yield changes. Then, the value of the coefficient of variation is 0.5, and the proportion value (α, β, γ) can be assumed to be (0, 1, 0). We can now then conclude empirically and statistically that corn production is highly volatile, and that declining yields are the cause of the volatility. When this analysis method is introduced, the coefficient of variation and contribution of various items can be estimated in the same way. Furthermore, if the estimated values are categorically analyzed, the production pattern in a certain period will be identified. The next section analyzes North Korea's agriculture based on the coefficient of variation and discusses the relationship between production patterns and policy changes.

4. Analysis of Variabilities in North Korean Agricultural Production

4.1. Basic Statistics

Due to the North Korean government's lack of comprehensive statistical data, the FAO's agricultural production statistics are used to assess the country's production variability. An analysis of crop production during the Great Famine period revealed that 6.05 million tons of grains, 3.64 million tons of vegetables, 1.34 million tons of fruits, and 0.12 million tons of nuts and other crops were produced. The economic reform period showed an increase in production to 7.35 million tons of grains, 3.80 million tons of vegetables, 1.43 million tons of fruits, and 0.13 million tons of nuts and other crops, an increase of 21.5%, 4.3%, 6.9%, and 11.1%, respectively, from the previous period. Under Kim Jong-Un's reign, grain production was 8.05 million tons, vegetables were 3.49 million tons, fruits were 0.16 million tons, and nuts and other crops were 0.16 million tons. Compared to the economic reform period, grains and fruits increased by 9.5% and 11.8%, respectively, but vegetables decreased by 8.1%.

The agricultural cultivation area during the three regimes fluctuated between 2.7 and 2.8 million hectares. During the Great Famine period, it was 2.73 million hectares. In the economic reform period, the area increased to 2.79 million hectares, a rise of 2.1% from the previous period, but decreased to 2.67 million hectares, a decrease of 3.6% compared to the economic reform period, during Kim Jong-Un's reign. By item group, the cultivation area during the Great Famine period was 2.18 million hectares for grains, 0.30 million hectares for vegetables, 0.16 million hectares for fruits, and 0.089 million hectares for nuts and other crops. These areas increased by 0.7%, 3.0%, 12.8%, and 11.3%, respectively, during the economic reform period. Under Kim Jong-Un's reign, the area of grains was 2.06 million hectares, vegetables were 0.29 million hectares, fruit was 0.23 million hectares, and nuts and other crops were 0.11

million hectares. Rice and corn had the highest proportion of grain production, followed by legumes. Cabbage and onions were the most cultivated vegetables, while apples were the most produced fruit.

Table 4 Agricultural Production and Cultivation Area in North Korea (1994~2018)

Unit: 1,000ton, 1,000ha

Classification		Production			Area		
		①Famine	②Reform	③K J-U reign	①Famine	②Reform	③K J-U reign
Grains (Top 5s)	Rice, paddy	2,068.3	2,383.4	2,620.6	577.9	578.0	502.2
	Maize	1,534.5	1,672.6	2,135.7	586.9	502.4	530.3
	Potatoes	1,149.9	1,847.3	1,941.1	113.8	171.4	166.3
	Sweet potatoes	291.4	376.6	485.3	22.7	28.3	36.4
	Beans, dry	291.9	320.5	317.3	334.5	365.0	363.2
	Sub Total	6,054.9	7,357.6	8,058.8	2,181.0	2,197.3	2,058.4
Vegetables (Top 5s)	Vegetables, fresh nes	2,234.2	2,334.9	2,100.2	186.8	189.7	172.4
	Cabbages and other brassicas	643.2	667.6	669.9	34.0	33.2	30.8
	Watermelons	105.2	103.9	93.2	5.5	6.0	5.9
	Onions, shallots, green	89.1	94.8	88.6	6.7	7.4	7.1
	Onions, dry	80.5	84.7	85.3	6.8	7.4	8.8
	Sub Total	3,646.8	3,804.8	3,495.0	305.5	314.8	289.7
Fruits	Apples	643.9	675.0	791.6	70.1	71.3	72.1
	Fruit, fresh nes	465.8	507.9	547.0	65.9	80.4	123.7
	Pears	123.6	133.5	146.7	13.1	13.6	14.1
	Peaches and nectarines	109.7	119.4	119.9	14.0	18.6	24.0
	Sub Total	1,343.0	1,435.8	1,605.2	163.1	183.9	233.9
Other	Tobacco, unmanufactured	62.6	68.0	84.8	43.0	47.1	56.5
	Seed cotton	34.1	34.9	39.3	18.7	19.0	19.8
	Nuts nes	5.7	10.1	15.3	4.2	7.3	10.8
	Hemp tow waste	11.8	13.3	14.4	17.5	19.4	20.7
	Chestnut	8.1	9.6	12.3	5.3	5.9	5.3
	Sub Total	122.3	135.9	166.1	88.7	98.7	113.1
Total		11,166.9	12,734.2	13,325.2	2,738.2	2,795.0	2,695.2

Note: ① Great Famine (1994~2001) ② The Economic Reform period (2002~2011) ③ Kim Jong-Un's reign (2012~Recent)
Source: Organized by authors using FAOSTAT

4.2. Results

The coefficient of variation was estimated and decomposed into the area, yield, and correlation effects to confirm the degree of variability in agricultural production. The coefficient of variation varied widely from 0.02 to 0.72 in the whole period. Specifically, the area and yield effects ranged from 0.01 to 0.99. On the other hand, the estimated value of the correlation effect was 0.00~0.01 for most items except for some items, such as soybeans and other fruits. This means that there is almost no interaction between the area and the yield effects. The following are the results of analyzing variability by periods.

(Great Famine) Looking at more details by the periods, the overall production variability during Great Famine period was remarkably high for cereals (excluding legumes and hops), showing 0.25 to 0.56. For vegetables, it ranged from 0.02 to 0.07 and for fruits from 0.02 to 0.05 (ⓐ). Analysing the production variability of the leading grain crops (rice, corn, soybean, wheat), the yield effects are higher than the area effects. On the other hand, the area effects are more prominent than the yield effects for the other crops (ⓓ vs. ⓖ). This is interpreted as a rapid decline in yields of main cereal crops due to adverse climatic and economic impacts during the period, and thus the expansion of the cultivated area of the other crops.

In Great Famine, the variabilities of vegetables are minor compared to grains. However, the figures for other vegetables, cabbage, and onions are bigger than those in different periods and their variabilities were mainly due to

the area effect (ⓓ vs. ⓖ). It is mainly caused because of the reduction in the cultivation area of various vegetables to make up for the shortage of main grain crop productions because the seeding periods of the food grain crops overlap that of vegetable crops, and they are in a substitute relationship. In the case of fruits, the variability was minor compared to the economic reformation period, and large compared to the Kim Jong-Un regime.

(Economic Reform Period) Production variabilities during the economic reform period are 0.01~0.15 for grains, 0.01~0.08 for vegetables, and 0.02~0.05 for fruits. The variabilities of most items have declined significantly compared to the Great Famine or have turned into a stable trend. During that time, the production of other grains except for rye, barley, and oats increased, and the variabilities changed into stable. This is due to the stable conversion of yields and therefore the increase in yield effects (ⓔ vs. ⓗ). The variabilities of vegetables increased in many items compared to Great Famine (ⓐ vs. ⓑ), which is due to the increase in the area effect thanks to the significant expansion of vegetable cultivation areas (ⓔ). In particular, the area effect at that time was at the level of 0.3-0.95%. Fruit variability increased compared to the Great Famine, and the yield effect was larger than the area effect. In other words, these changes mean that the production and yield of main grain crops increased compared to the previous period during the economic reform period, and agricultural production entered the stabilization period, such as reduced variability. The large change (expansion) in the cultivation area of vegetable crops is interpreted as an increase in spring vegetable production based on securing stable conditions.

(Kim Jong-Un's era) During the reign of Kim Jong-Un, the production variability was 0.02~0.35 for grains, 0.01~0.09 for vegetables, and 0.01~0.02 for fruits (ⓒ). It shows increased grain variability, no meaningful change in vegetables, and a decrease variability in fruits (ⓑ vs. ⓒ). Looking at each item in detail, the production of beans and pulses decreased compared to the previous period, but the productions of staple crops such as rice, corn, and potatoes were increased. Looking at production variability, the coefficients of variation for rice and corn are relatively small showing 0.11 for rice and 0.07 corn. In contrast, those for potatoes, sweet potatoes, soybeans, wheat, and barley exceed 0.2, indicating high variability. There is a notable phenomenon here. Although the cultivated areas of grain crops in North Korea are decreasing (Table 4), the variabilities of many other grain crops have increased mainly due to the area effect (ⓔ vs. ⓕ in Table 5) at the same time. It is interpreted because of the land adjustment thanks to the expanded autonomy in farming activity, especially during the Kim Jong-Un's regime.

The variabilities of vegetable production during the Kim Jong-Un regime were similar or decreased compared to the previous period (ⓑ vs. ⓒ). Looking at the results by the individual crops, the production for cabbage, dried onion, cucumber, and eggplant increased compared to the previous period (Table 4), whose coefficients of variation are less than 0.04. In contrast, the production for watermelon, shallot onion, pumpkin, and other gourds and garlic decreased compared to the previous period and their variability exceeded 0.03. This was relatively large due to the area effect. The variabilities of fruit production decreased compared to the previous period (ⓑ vs. ⓒ). However, the production of all fruit items increased compared to the earlier period, and their coefficient of variation was less than 0.02, which was a low level. Furthermore, for apples and pears, the yield effect induced variability in production, whereas for peaches and other fruits, the area effect was the prominent factor-induced variability.

The agricultural situation in North Korea has been generally stable since the Great Famine period. In particular, the variability of the main crops during the Kim Jong-Un administration has been stable, with most fluctuations occurring in the yield. The production variability of major crops such as rice, corn, cabbages, and apples are due to the yield effects. For other crops, however, production variability is caused by area effects. This difference emerged after Kim Jong-Un took office, as the target amounts and cultivation areas of the main crops continued to be determined by central management using existing methods, while autonomy was granted to other crops. By examining the correlation between changes in agricultural production and the coefficient of variation during the Kim Jong-un regime, we can confirm a shift in agricultural policy during that period.

4.3. Evaluation of Agricultural Production Patterns in Kim Jong-Un's Era

The aforementioned results elucidate two salient discussion points regarding the disparities between grain and horticultural production patterns.

Firstly, the grain production trajectory exhibits noteworthy shifts. While grain production has demonstrated a consistent upward trend since 1994, the stability patterns have fluctuated markedly.

Grain production variabilities (excluding legumes and hops) were exceptionally pronounced during the Great Famine period (0.25~0.56), but they turned to stable trends during the economic reform period (0.01~0.15) before reverting to a state of instability under Kim Jong-Un's leadership (0.02 to 0.35). This empirical evidence leads to the rejection of the null hypothesis posited in the research hypothesis concerning grain production.

Table 5 Results of Agricultural Production and Decomposition of Variation Coefficients

Classification		Coefficient of variation			Area effect			Yeild effect			Correlation coefficient		
Item		ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ	ⓖ	ⓗ	ⓘ	ⓙ	ⓚ	ⓛ
Cereal	Rice, paddy	0.25	0.10	0.11	0.02	0.01	0.36	0.98	0.99	0.64	0.00	0.00	0.00
	Maize	0.53	0.07	0.07	0.04	0.16	0.21	0.95	0.84	0.79	0.00	0.00	0.00
	Potatoes	0.56	0.10	0.23	0.96	0.61	0.98	0.04	0.40	0.02	0.00	-0.01	0.00
	Sweet potatoes	0.39	0.08	0.23	0.99	0.84	0.96	0.01	0.16	0.04	0.00	0.00	0.00
	Beans, dry	0.06	0.04	0.02	0.85	0.83	0.84	0.15	0.17	0.16	0.00	0.00	0.00
	Soybeans	0.07	0.01	0.27	0.14	0.64	0.93	0.85	0.36	0.08	0.00	0.00	-0.01
	Millet	0.21	0.14	0.03	0.99	0.93	0.91	0.01	0.07	0.09	0.00	0.00	0.00
	Rye	0.15	0.01	0.02	1.00	0.78	1.00	0.00	0.22	0.00	0.00	0.00	0.00
	Wheat	0.28	0.13	0.28	0.28	0.61	0.94	0.73	0.38	0.06	-0.01	0.00	0.00
	Sorghum	0.33	0.15	0.01	0.80	0.92	0.58	0.20	0.08	0.42	0.00	0.00	0.00
	Barley	0.52	0.10	0.35	0.56	0.46	0.95	0.38	0.55	0.05	0.07	-0.01	0.00
	Oats	0.37	0.03	0.15	0.98	0.38	0.99	0.02	0.62	0.01	0.00	0.00	0.00
	Hops	0.04	0.04	0.01	0.69	0.17	0.87	0.31	0.83	0.13	0.00	0.00	0.00
Vegetable	Vegetables, fresh nes	0.05	0.05	0.02	0.16	0.80	0.87	0.84	0.20	0.13	0.00	0.00	0.00
	Cabbages and other brassicas	0.07	0.05	0.04	0.90	0.86	0.11	0.10	0.14	0.89	0.00	0.00	0.00
	Watermelons	0.04	0.07	0.02	0.44	0.64	0.76	0.57	0.37	0.24	0.00	-0.01	0.00
	Onions, shallots, green	0.03	0.04	0.02	0.79	0.45	0.98	0.21	0.55	0.02	0.00	0.00	0.00
	Onions, dry	0.03	0.02	0.01	0.64	0.46	0.44	0.36	0.55	0.56	0.00	0.00	0.00
	Cucumbers and gherkins	0.04	0.08	0.08	0.81	0.90	0.98	0.19	0.10	0.02	0.00	0.00	0.00
	Pumpkins, squash and gourds	0.03	0.06	0.03	1.00	0.83	0.92	0.00	0.17	0.08	0.00	0.00	0.00
	Garlic	0.05	0.06	0.09	1.00	0.95	1.00	0.00	0.05	0.00	0.00	0.00	0.00
	Cucumbers and gherkins	0.02	0.01	0.01	0.88	0.53	0.27	0.12	0.47	0.73	0.00	0.00	0.00
	Tomatoes	0.05	0.03	0.00	0.12	0.30	0.19	0.88	0.70	0.81	0.00	0.00	0.00
	Eggplants (aubergines)	0.04	0.02	0.01	0.97	0.60	0.64	0.03	0.40	0.37	0.00	0.00	0.00
	Chillies and peppers, green	0.04	0.07	0.04	0.83	0.64	0.64	0.17	0.36	0.36	0.00	0.00	0.00
Fruit	Apples	0.02	0.05	0.02	0.58	0.11	0.23	0.42	0.88	0.77	0.00	0.00	0.00
	Fruit, fresh nes	0.03	0.04	0.02	0.74	0.68	0.58	0.26	0.34	0.43	0.00	-0.02	-0.02
	Pears	0.04	0.03	0.01	0.93	0.64	0.06	0.07	0.36	0.94	0.00	0.00	0.00
	Peaches and nectarines	0.05	0.02	0.01	0.94	0.45	0.55	0.06	0.56	0.46	0.00	-0.01	-0.01
Other	Tobacco, unmanufactured	0.02	0.07	0.05	0.36	0.88	0.98	0.64	0.12	0.02	0.00	0.00	0.00
	Seed cotton	0.06	0.03	0.01	0.12	-	0.44	0.88	-	0.56	0.00	-	0.00
	Nuts nes	0.30	0.13	0.30	0.95	0.51	1.00	0.04	0.50	0.00	0.00	0.00	0.00
	Hemp tow waste	0.05	0.04	0.02	0.40	0.90	0.98	0.60	0.10	0.02	0.00	0.00	0.00
	Chestnut	0.07	0.10	0.03	0.94	0.21	0.28	0.06	0.79	0.72	0.00	-0.01	0.00

Note: The classification by ⓐⓓⓖⓙ Great Famine (1994~2001) ⓑⓔⓗⓚ The Economic Reform period (2002~2011) ⓒⓕⓘⓛ Kim Jong-Un's reign (2012~Recent)
Source: Calculations by the author using FAOSTAT

The observed variations in factors influencing production stability can be attributed to ecological and economic rehabilitation efforts during the economic reform period, coupled with increased autonomy and the implementation of multi-cropping systems during Kim Jong-Un's regime. A more granular analysis of individual crops reveals an intriguing pattern: the variability changes in major grain crops such as rice and corn are predominantly yield-driven, with minimal alterations in coefficients of variance but significant production fluctuations. This phenomenon can be interpreted as a consequence of production quotas and mandatory cultivation requirements imposed by centralized production plans, which constrain autonomy within the primary grain production system. This lack of systemic flexibility renders North Korea particularly vulnerable to natural disasters, potentially impacting grain yields.

Conversely, inferior grain crops such as wheat, barley, and soybeans exhibited substantial declines in production and high variabilities, primarily attributable to area effects. The reduction in barley production can be ascribed to its status as an inferior good, leading to diminished cultivation

areas. The gradual decrease in soybean and wheat harvest areas may be a result of increased imports of related processed products (e.g., wheat flour, edible oil) from China (Kim et al., 2019). Sorghum and millet, however, displayed contrasting characteristics, demonstrating strong cold resistance and minimal susceptibility to meteorological and climatic variations. Consequently, their variability is predominantly influenced by area effects rather than yield changes.

Secondly, a significant proportion of vegetable and fruit crops maintained stability, with no substantial alterations in production or variability. This observation precludes the rejection of the null hypothesis for horticultural products. Vegetable production experienced an increase during the economic reform period but subsequently declined during Kim Jong-Un's regime. Throughout the entire study period, the coefficients of variation for all vegetable crops remained below 0.10, indicating greater stability compared to grain crops. Previous studies (Choi, 2017; Kwon, 2018) have suggested that increased demand, driven by rising household incomes following market expansion, had stimulated production of fresh foods, protein sources, fruits, vegetables, and processed foods. The current findings, which diverge from these earlier observations, warrant further investigation. Two potential explanations can be posited for this discrepancy.

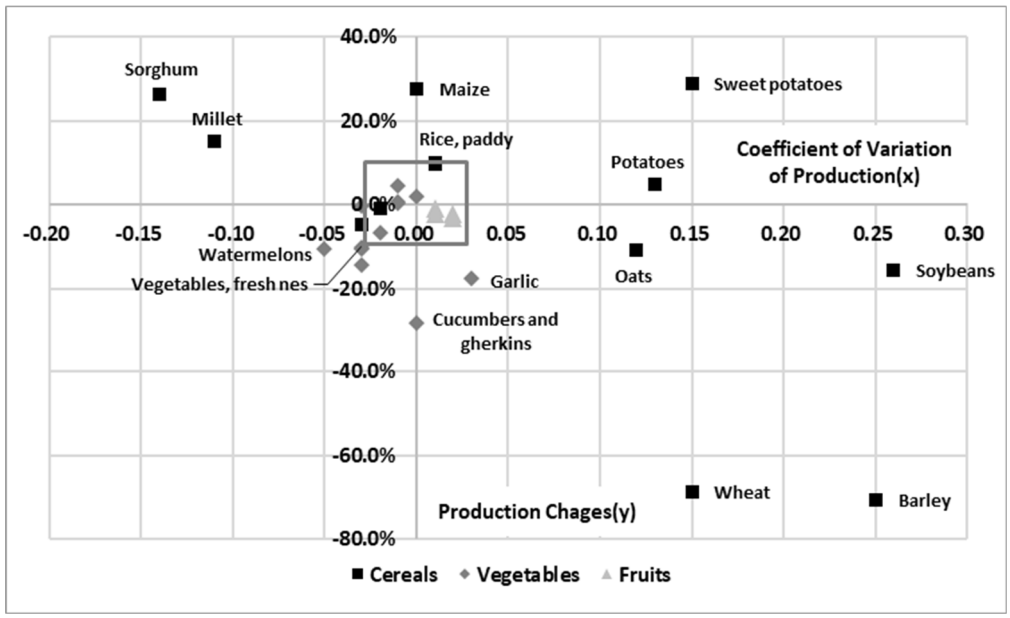

Figure 1 Changes in product groups and production patterns by item during the Kim Jong-Un era

Note: CV of production changes is calculated by ⓒ-ⓑ, Production Changes is calculated by production of economic reform era versus production of Kim Jong-Un era. Thus, Littles changes in agricultural production patterns are observed by period in square area (H_0). Range of square is Production Changes in –10%~10% and CV of production changes in -0.025~0.025.
Source: Calculations by the author using FAOSTAT

The analysis of vegetable production patterns in North Korea reveals two distinct phenomena that merit further discussion.

Firstly, the cropping system suggests a potential substitutive relationship between certain vegetables and food crops. Notably, the coefficients of variation in vegetable production (or cultivation area) do not exhibit significant increases. Previous research has established a decrease in the cultivated area of wheat and barley, which are spring crops in North Korea. However, various vegetables, also spring crops, show no significant change in their coefficients of variation. This observation can be contextualized within North Korea's economic and food security challenges. It suggests that while vegetable production may be suboptimal, the deficit is not severe enough to pose an immediate threat to food security. Consequently, this indicates a possible de-prioritization of vegetable production in agricultural policy. Nevertheless, during Kim Jong-Un's administration, there has been an increase in area effects compared to previous periods. This shift can be attributed to policies permitting free production in vegetable gardens and unrestricted disposal of produce, facilitated by market expansion, which has led to an increase in cultivation areas.

Secondly, certain vegetable crops appear to be subject to significant state control. The low variability observed in

important vegetable and fruit crops, such as cabbage and apples, suggests that these are state-managed items, similar to main grain crops. Primary vegetables (including Kimchi ingredients like cabbage, radish, and red pepper) are predominantly produced in specialized Namsae (vegetable) collective farms or by Namsae sub-teams within collective farms. However, Kwon et al. (2019) note the existence of a passive form of private farming for vegetables that are relatively easy to cultivate and have market demand. These are primarily grown for market sale on non-arable lands in collective farms or small private plots.

The centralized allocation of cultivation areas and production targets for important crops such as cabbage and apples by the government appears to result in a concentration of North Korea's limited inputs (labor, fertilizer) in their production, leading to relatively small production variabilities. This hypothesis is further corroborated by the observation that most of the production variabilities for these crops stem from yield effects. In contrast, the variabilities of other non-controlled vegetables are primarily attributable to area effects.

This dichotomy in vegetable production patterns reflects the complex interplay between centralized agricultural planning, market forces, and food security considerations in North Korea's agricultural sector.

5. Conclusions

This study examines the interplay between North Korea's economic policies and agricultural production variability, with a particular focus on the post-Great Famine era. Under Kim Jong-Un's administration, the agricultural policy trajectory can be characterized as a dichotomous approach: state-directed management of strategically important crops, juxtaposed with increased autonomy for collective farms in the cultivation of secondary crops. To quantify the impact of these policy shifts on agricultural production variability, we employed coefficients of variation and disaggregated these variabilities into area and yield effects. Our analysis yielded two salient findings.

Firstly, the North Korean government has maintained stringent control over the production of major crops, particularly grains. Despite experiencing acute food shortages from the mid-late 1990s through the 2000s, annual food production has stabilized at approximately 4.5 to 4.8 million tons since the 2010s. The observed expansion in volatility of minor grain production can be interpreted as a grassroots effort to supplement food supplies. This suggests that while the major crop policies have achieved partial success, North Korea's grain production remains insufficient to meet minimum requirements.

Secondly, North Korean authorities have granted greater autonomy in the production of non-major crops and demonstrated flexibility in responding to environmental changes affecting these crops. Our analysis reveals that the variability in horticultural crop production has remained stable with minimal fluctuations. This finding is significant as it contradicts previous studies postulating that market expansion in North Korea would stimulate consumption power and, consequently, promote horticultural crop production. We posit that this discrepancy may be attributed to North Korea's underdevelopment, persistent food insecurity, and low consumption levels.

This study elucidates that the production variability of staple crops is undergoing significant changes attributable to fluctuations in crop yields. Upon reviewing the results of this study, it can provide implications for North Korea's agricultural policy. North Korea has acknowledged a food-deficient situation in nation into the 2020s. Consequently, there exists an imperative to formulate agricultural policies capable of mitigating external factors to ensure stable yields of principal food crops. Strategies for maintaining agricultural productivity may be explored within the domains of production systems, agronomic practices, and distribution networks (Em, 2024; Choi et al., 2024; Kobayashi & Suh, 2023).

The progressive marketization of North Korea since the 2010s has precipitated an amelioration in the distribution conditions for agricultural inputs, including fertilizers, plastic films, and small-scale farm implements, compared to preceding periods. Concurrently, North Korean authorities are reportedly exerting concerted efforts to enhance agricultural infrastructure (Lee, 2016), encompassing land reclamation projects and embankment construction, despite resource limitations. Finally, given that agricultural methodologies are fundamentally technological developments, their advancement necessitates adoption of a long-term investment perspective in both policy formulation and implementation within North Korea's evolving agricultural landscape.

Considering the pragmatic constraints inherent in North Korean agriculture, it is imperative to explore implementable policy interventions. This study proposes the establishment of an agricultural early warning system within North Korea. Such systems have been demonstrated to offer multiple advantages, including the anticipation of meteorological variations and agricultural calamities, as well as the provision of actionable response protocols (Park et al., 2022; Sharafi et al., 2016; Jin et al., 2012). While reports indicate that the North Korean Meteorological Administration has been proactively issuing agricultural disaster forecasts since the 2020s, information regarding the operational status of any existing early warning system remains limited.

Should such a system be established and operationalized, it may present a viable policy option for consideration by North Korean authorities. In South Korea, the Rural Development Administration oversees an agricultural early warning system that reportedly furnishes services encompassing region-specific meteorological forecasts, crop growth-based impact predictions, crop-specific hazard anticipation data, and the dissemination of mitigation strategies to agricultural practitioners. The prospective implementation of an early warning system by North Korean agricultural authorities could potentially serve as a feasible avenue for inter-Korean cooperation initiatives.

It is important to acknowledge the limitations of our study, particularly the absence of analysis regarding the impact of international sanctions against North Korea. However, we anticipate that even with the inclusion of data up to 2020, improving our analysis may prove challenging due to the potential inadequacy of the mean-variance approach used for calculating the coefficient of variation. Future research endeavors will focus on refining our analytical techniques to more comprehensively assess the effects of sanctions on North Korea's agricultural sector.

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