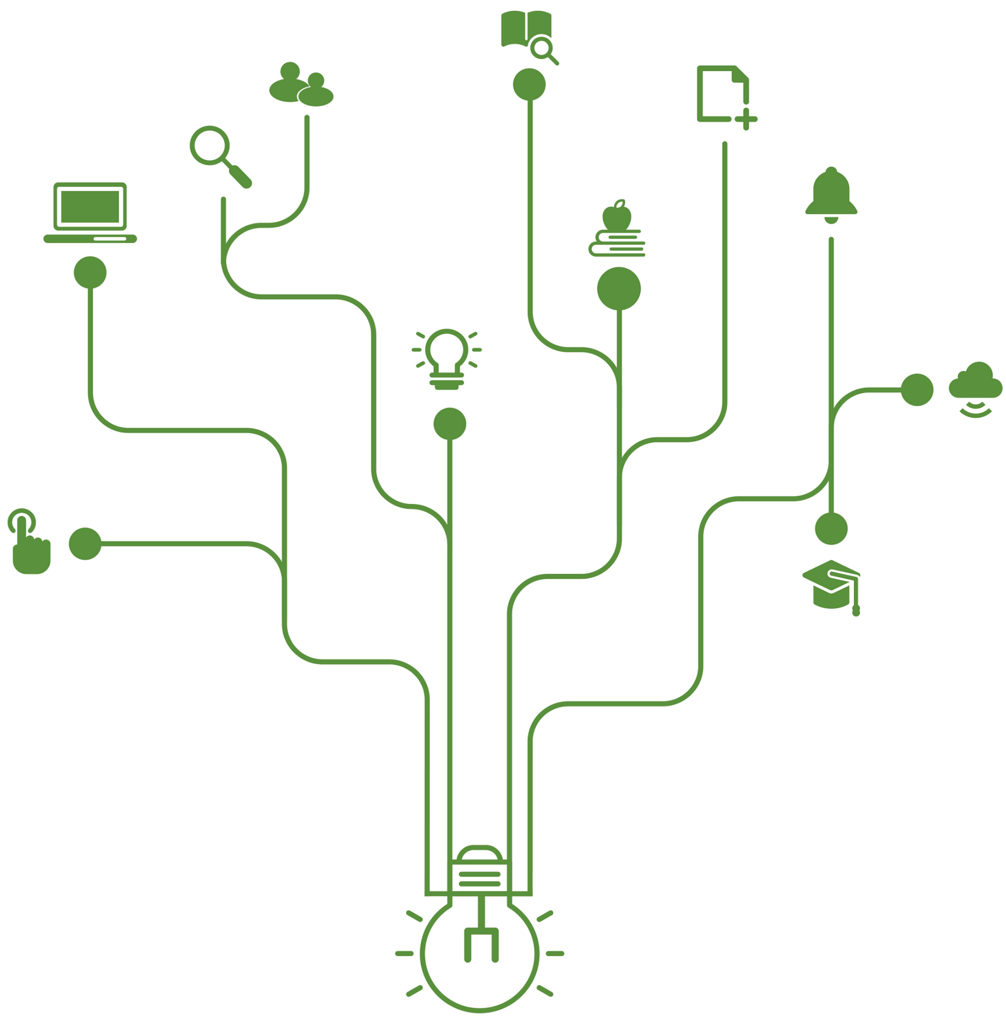
Development Studies Series 04

Constructing County-Level Data for Agricultural Inputs and Analyzing Agricultural Productivity, 1951-1980

이 철 희



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Executive Summary

Since the liberation from the Japanese occupation in 1945, South Korea has achieved substantial improvement in the nutritional status of the population, as indicated by the increase in adult heights. Recent studies suggest that increase in local food availability was an important contributing factor of the increased heights of the individuals born prior to 1960. Besides its significance as a long-term factor of improvement in nutritional status, measuring agricultural productivity and determining its major factors in the 1960s and 1970s is an important issue in its own right given the relative size of the Korean agricultural sector at the time. However, in-depth studies on agricultural productions in the past are restricted by the shortage of micro-level data covering the periods prior the 1980s.

In this study, I collected data sources (statistical yearbooks published by each province and county) and constructed databased containing variables regarding major inputs of agricultural productions in the 1960s and 1970s. I examined how major agricultural inputs (including land, labor, agricultural machines, and chemical fertilizers) changed over time and across provinces. By linking the data on inputs with the county-level agricultural production data, I also estimated agricultural production functions, focusing on the production of rice, the most important crop in Korean agriculture.

The present study is distinct from previous studies on Korean agricultural production in several respects. First, this research investigates agricultural production in Korean prior to 1980 based on county-level data, whereas most of previous studies that looked into the period are largely based on aggregate data of the country as a whole. Secondly, this study is the first to utilize the comprehensive county-level agricultural data on both outputs and inputs that are drawn from statistical yearbooks covering the two decades from 1960 to 1980. Finally, the present studies consider a wider range of agricultural inputs than those included in previous studies, including individual machinery and chemical fertilizer.

The area planted with all food crops and the size of rice-cultivating area increased and reached the peak in the mid 1965s. Afterwards, it declined over time. During the Korean War (1950 to 1953), the cultivated area temporarily diminished perhaps due to wartime destructions. The area of arable lands considerably differed by province. During the three decades under study, the province with the largest planted area was Gyeongbuk, followed by Jeonnam and Gyeongnam. By the 1970s, Jeonnam overtook Gyeongnam at the number one province in terms of the arable land area.

The farm population sharply fell from 1949 to 1951 as a consequence of wartime deaths. After the Korean War, the farm population gradually increased until 1967, and then declined over time thereafter. During the three decades under study, the top three provinces in terms of the size of farm population were Jeonnam, Gyeongbuk, and Gyeongnam. Even if the farm population is standardized according to age and gender compositions, these patterns of changes in labor input across times and provinces remain unchanged.

The number of major agricultural machines, such as power tillers, auto sprays, and tractors, increased sharply from the early 1970s. However, the trends should be cautiously interpreted because the relatively small number of machines in the early 1960s could result from the larger number of missing observations. Nevertheless, it seems evident that the availability of agricultural machines increased over time, although we cannot be sure how much under-reporting affects the real trend. If we compare years 1969 and 1980 when the number of counties with the number of machines reported remained unchanged, the number of power tillers increased more than 30 times. The increasing trend is similar to those of auto sprays and tractors. The patterns of changes in the use of agricultural machines substantially differed by region.

As in the case of agricultural machines, the use of chemical fertilizers dramatically increased from the early 1970s. Again, however, the trends should be taken cautiously because there were more counties in the 1960s where fertilizer consumption is unreported than in the 1970s. To address such potential problems, I also examined the yearly consumption divided by the number of counties (i.e., the average consumption per county). The results indicate that the rapid increasing trend largely captures the increase in the number of counties reporting fertilizer consumption. Furthermore, large fluctuations in each province's fertilizer consumption are observed. These results suggest that samples with information on fertilizers should be selected so that variables for chemical fertilizers can be considered in the estimation of agricultural production functions.

Combining the county-level data on agricultural outputs and inputs, I estimated production functions of rice, the most important crop in Korean agriculture. The variable pertaining to land input is defined as the size the rice-cultivating area (measured in hectare) in each county in a given year. For labor input, I use the standardized population living in farm households cultivating rice. Since variables pertaining to capital inputs are not universally reported in provincial or county Annual Statistics, there is a tradeoff between considering more variables on inputs and additional loss of observations. I attempt to circumvent this problem in the following two ways. Firstly, I estimate agricultural production functions excluding the variable on capital inputs, and then extend the model by including additional capital inputs to examine the effects of the sample selections arising from missing observations of capital inputs. Secondly, I only focus only on major components of capital inputs to achieve a balance between omitted variables and missed observations. Finally, I included only the counties with information on a particular type of capital input (machine or fertilizer) to avoid bias arising from underreporting in early periods.

The results of regressions suggest that land and labor inputs have very strong positive relationship with the amount of rice production. In particular, the size of land input alone explains more than 95% of variations in rice productions across counties and years. If included separately, difference in labor input account for 83% of variations in rice outputs across counties and years. If the two inputs are included at the same time, the coefficient for land (0.99) is estimated much larger in magnitude than that for labor (0.05), confirming the huge importance of land in rice production in the 1960s and 1970s. If the year fixed is controlled, the coefficient for land diminishes by about 0.1 whereas the coefficient for labor increases by roughly the same magnitude. It is likely that year fixed effect captures the contributions of omitted factors that changed over time, including increased capital inputs and technical progress. The regression results imply that such omitted factors are positively related to land input, and negatively related to labor input. This is consistent with the fact that labor input decreased more rapidly than land input during the period under study.

I also conducted regressions in which a measure capital input (composite index of agricultural machines) is included. The coefficient for machine is positive and statistically significant, but the additional input explains only 3% of the variations in rice production across counties and years. If machine is additionally included, the coefficients for land and labor do not change much. Inclusion of year fixed effect reduces the coefficients for land and machine, whereas the contribution of labor becomes larger in magnitude. In particular, the coefficient for machine diminishes by more than two thirds. This indicates that the estimated contributions of agricultural machines largely capture the changes in capital input and output across times.

In sum, the results of regression analyses suggest that local rice production in Korea during the period from 1960 to 1979 was largely determined by land and labor inputs. Changes in these two factors explain more than 95% of variations in rice production across counties and years. It is difficult to estimate accurately the contributions of capital inputs to agricultural production because data are available only for selected capital inputs and for selected places and years. The results based on using three major agricultural machines of the time (power tillers, automatic sprays, and tractors) suggest that capital inputs also played significant roles in changing agricultural production, especially across times.

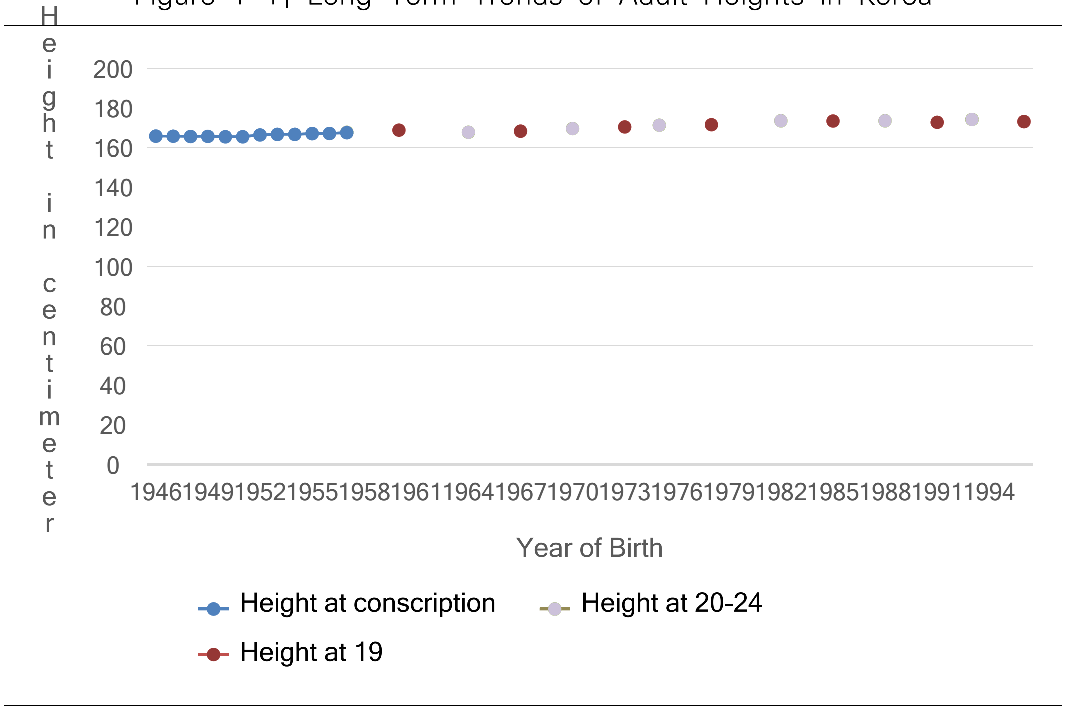
Given the currently available county-level data on agricultural inputs, it would be reasonable to use the number of major agricultural machines as an index of capital input in estimating agricultural production function. Land, labor, and agricultural machines explain over 98% of the variations in rice production across counties and years. Using the data and estimated regression coefficient for each input, it will be possible to estimate the agricultural total factor productivity as well as each factor productivity in each county and year. I remain it as future research agenda to investigate how natural, institutional and technological factors (such as natural disasters, local organizations, and new methods) affected these measures of local agricultural productivity.

Introduction

As South Korea achieved rapid economic growth since its liberation from the Japanese occupation in 1945, the nutritional status of the population has improved over time. [Figure 1-1] shows the long-term trend of the average height around age 20. The mean height of the subject of the 1950 birth cohort at age 20 was 165.5cm. The average height of the 1984 birth cohort at age 19 was 173.4cm. Of the increase in height by 8cm during the 25 years, more than 40% (3.4cm) was gained by 1960. The growth of adult heights, a most widely used index of net nutritional status during the growth period, should be affected by secular increase in agricultural productions in Korea. A recent study based on county-level data on agricultural production suggests that improved nutritional availability explains 30% to 50% of the increase in height between the 1951 and 1957 birth cohorts. [Figure 1-2] shows that the total amount of rice production and rice production per farm household substantially increased over time.

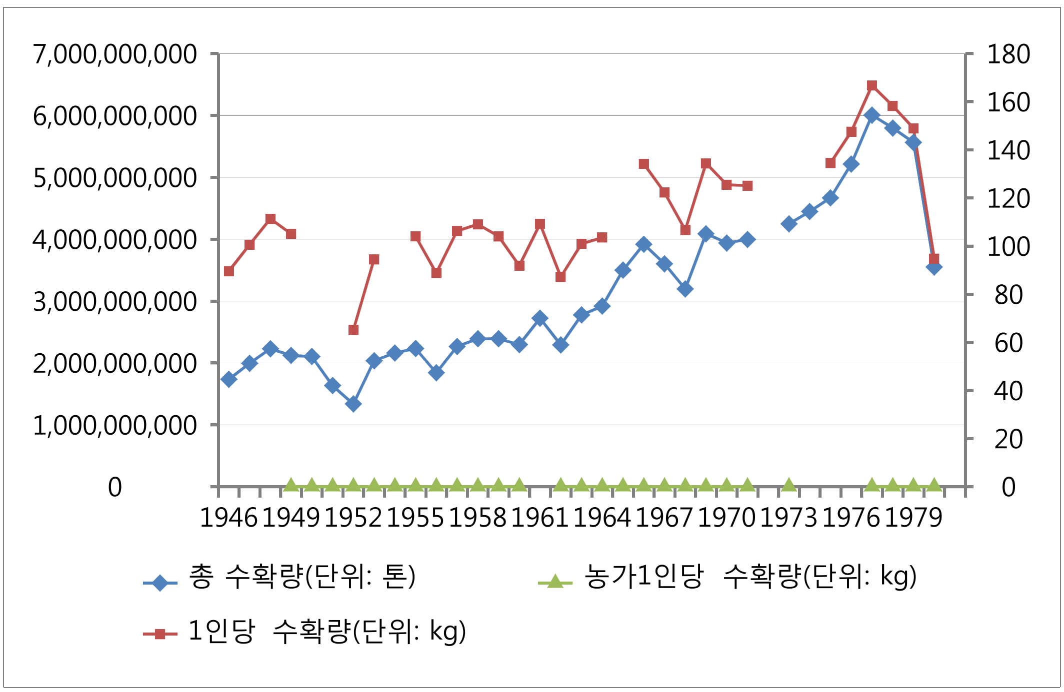
Besides its significance as a long-term factor of improvement in nutritional status, measuring agricultural productivity and determining its major factors in the 1960s and 1970s is an important issue in its own right given the relative size of the Korean agricultural sector at the time. However, in-depth studies on agricultural productions in the past are restricted by the shortage of micro-level data covering the periods prior the 1980s. With the financial support of the KDI School, I have recently constructed province- and county-level data on agricultural productions, and created variables pertaining to local nutritional availability (Lee 2018). If the production data can be used in conjunction with data on agricultural inputs, I expect that many of the issues that have been untouched can be tackled with the county-level data.

Figure 1-1| Long-Term Trends of Adult Heights in Korea



Source: Lee (2018)

Figure 1-2| Rice Production by Year: Total, Per Capita, and Per Farm Population



With these backgrounds, the main purposes of the present study are as follows. Firstly, I collected data sources (statistical yearbooks published by each province and county) and constructed databased containing variables regarding major inputs of agricultural productions in the 1960s and 1970s. Secondly, I introduce the data, and describe how a number of major agricultural inputs changed over time and across years. Finally, I estimate agricultural production functions based on county-level data, focusing on the production of rice, the most important crop in Korean agriculture.

There are a large number of studies regarding the measurement of the agricultural productivity or estimation of agricultural production function in Korea, as agriculture is deemed to be a core sector of the country despite its recent decline in volume (Hwang, 1998; Kwon, and Kim, 2000a; Kwon, and Kim, 2000b; Lee, 2008; Kwon, 2010; Yu, Hwang, and Yoo, 2014; Kwon, Yoon, and Ban, 2015; Yu, 2015; Kwon, and Ban, 2016). While most of the studies focused on the agricultural productivity at the national level, regional-level investigation has also been executed in latest researches (Yu, 2015; Kwon, and Ban, 2016).

The studies on agricultural productivity require data on the inputs and outputs regarding agriculture, which cover a long period of time in usual. Therefore, appropriate consideration on the changes in relative prices is indispensable. In most Korean literatures, Törnqvist index, a kind of changing-weight index, is extensively utilized, since it allows the changes in relative prices over time and the use of trans-log production function. The analysis from the use of Törnqvist index shows that previous studies that utilized fixed-weight indices might have underestimated the contribution of the total factor productivity to the augmentation of the agricultural production in South Korea (Hwang, 1998).

In most studies, the annual growth rate of the total factor productivity of the agricultural sector in South Korea on average is estimated to be around 2% (Hwang, 1998; Kwon, and Kim, 2000a; Kwon, and Kim 2000b). Yet, the annual growth rates have not been held constant, as the productivity stagnated around mid-1980 (Kwon, and Kim 2000a). This productivity stagnation was overcome by large scale investment subsidy, which accentuates the importance of investment on technology (Kwon, and Kim 2000b). Especially from 1971 to 2007, 26% of the increase in agricultural productivity is explained by R&D (Kwon, 2010).

Analyses on more recent data yield some interesting points. Aggregating inputs into capital, labor, land, and intermediate inputs, productivity change in South Korea from 1971 to 2013 can be identified with three distinct phases: the stage of high growth rates in inputs and outputs from 1971 to 1986, the stage of near-zero growth rate in inputs and low growth rate in outputs from 1987 to 1997, and the stage of negative growth rate in inputs and outputs from 2000 to 2013 (Kwon, Yoon, and Ban, 2015). Furthermore, sectorial analysis on data from 1955 to 2012 shows that the change in the growth rates were not unilateral across the subsectors of agriculture (Yu, Hwang, and Yoo, 2014).

Beyond the studies on national-level agricultural productivity, recent studies delved into regional differences (Yu, 2015; Kwon, and Ban, 2016). Parametric estimation on the regional production functions shows some dissimilarities in productivity across different regions, where Cobb-Douglas, trans-log, and stochastic frontier production functions are used (Yu, 2015). Moreover, utilizing micro-level production data from 2003 to 2012, the regional stochastic frontier production function and the national meta-frontier production function are also estimated (Kwon, and Ban, 2016). Such regional dissimilarity in agricultural productivity is also found in China from meta-frontier analysis (Chen, and Song, 2008).

There are literatures that predict how climate change would affect agricultural outputs (Deschênes, and Greenstone, 2007; Izaurralde, Rosenberg, Brown, and Thomson, 2003). Upon analyzing two climate change scenarios, the first Intergovernmental Panel on Climate Change (IPCC) report and Hadley Centre's Second Coupled Ocrean-Atmosphere General Circulation Model, the annual variations in temperature and precipitation are expected to increase annual profits by $1.3 billion in 2002 dollars (Deschênes, and Greenstone, 2007).

The present study is distinct from previous studies on Korean agricultural production. First, this is one of very rate studies that investigate agricultural production in Korean prior to 1980 based on county-level data. Most of the studies that looked into the period are largely based on aggregate data of the country as a whole. Meanwhile, recent studies that analyzed micro-level farm data largely concern with the period after 1980. Secondly, this study is the first to utilize the comprehensive county-level agricultural data on both outputs and inputs that are drawn from statistical yearbooks covering the two decades from 1960 to 1980. Previous studies that used similar data paid attention to selected years and counties. Finally, the present studies consider a wider range of agricultural inputs including individual machinery and chemical fertilizer.

Data on County-Level Agricultural Inputs

County-level data on agricultural inputs are not readily available in machine-readable form. As confirmed by the previous research that collected and used data on agricultural outputs (Lee 2018), the statistical yearbooks published by each province and county are one of the most reliable sources that report county-level agricultural inputs annually in a consistent manner. Utilizing these sources, I constructed county-level data on all major agricultural inputs.

Provincial and county statistical yearbooks employ a bottom-up approach to produce the annual statistics in various fields. First of all, each county compiles data reported from lower public administrative centers and publishes its own statistical yearbook. Simultaneously, the related sections or bureaus of each province compiles data reported from the counties they control and publishes provincial statistical yearbook annually. Lastly, the National Bureau of Statistics collects all of these data and publishes the Korean Statistical Yearbook. This process has been repeated every year since 1961.

The records used for our data constructions are available online or in several public libraries. The online sources include the websites of the National Archives of Korea (archives.go.kr), National Assembly Library (nanet.go.kr), Statistics Korea Library (lib1.kostat.go.kr), and several local governments. Many statistical books are deposited in these websites in pdf or e-book files. A few of the records are available only from off-line sources. We collected the records that are unavailable online from the Statistics Korea Library, Suwon Library of Seoul National University, National Assembly Library, and National Archives of Korea either through borrowing volumes or reproducing copies with the permission of the library staff members. <Table 2-1> presents the list of the sources utilized for constructing our data on input factors of local agriculture.

Table 2-1| List of Data Sources Used in Construction of Dataset

Data Sources	Publication Year	Form
The *Seoul Statistical Yearbook*	1960~1990	▫ pdf files
The *Busan Statistical Yearbook*	1962~1990	▫ 1964, 1967: e-books from the National Archives of Korea ▫ 1973: an e-book from the National Assembly Library ▫ The rest: e-books from the Busan Metropolitan City
The *Gyeonggi Statistical Yearbook*	1961~1965 1967~1990	▫ pdf files
Statistical yearbooks of counties under the control of Gyeonggi Province	1966	▫ Gapyeong, Suwon, Siheung, Anseong, Incheon, Paju, Pyeongtaek, Hwaseong: pdf files ▫ Ganghwa, Goyang, Gwangju, Gimpo, Bucheon, Yangju, Yangpyeong, Yeoju, Yeoncheon, Yongin, Uijeongbu, Icheon, Pocheon: jpg files capturing some pages of books from Statistics Korea Library
The *Gangwon Statistical Yearbook*	1961~1965 1967~1990	▫ pdf files
Statistical yearbooks of counties under the control of Gangwon Province	1966	▫ Gangneung: an e-book from the National Assembly Library ▫ Goseong, Sokcho, Jeongseon, Cheorwon, Chunseong, Chuncheon: jpg files capturing some pages of books from Statistics Korea Library
The *Chungbuk Statistical Yearbook*	1961~1965 1967~1990	▫ 1961, 1963, 1968~1969: jpg files capturing some pages of books from the Statistics Korea Library ▫ The rest: e-books from the National Archives of Korea
Statistical yearbooks of Counties under the control of Chungbuk Province	1966	▫ Goesan, Danyang, Boeun, Yeongdong, Okcheon, Eumseong, Jecheon, Jungwon, Jincheon, Cheongwon, Cheongju, Chungju: jpg files capturing some pages of books from Statistics Korea Library
The *Chungnam Statistical Yearbook*	1961~1965 1967~1990	▫ pdf files
Statistical yearbooks of counties under the control of Chungnam Province	1966	▫ Gongju, Geumsan, Nonsan, Daejeon, Seosan: jpg files capturing pages of books from Statistics Korea Library
The *Jeonbuk Statistical Yearbook*	1962~1965 1967~1990	▫ 1962~1965, 1967 : e-books from the National Archives of Korea ▫ The rest: pdf files
Statistical yearbooks of counties under the control of Jeonbuk Province	1966	▫ Gunsan, Gimje, Namwon, Muju, Buan, Okgu, Wanju, Iri, Iksan, Imsil, Jangsu, Jeongeup, Jinan: jpg files capturing some pages of books from the Statistics Korea Library ▫ Sunchang: an e-book from the National Assembly Library ▫ Jeonju: an e-book from the National Archives of Korea
The *Jeonnam Statistical Yearbook*	1963 1965 1967~1990	▫ 1963: jpg files capturing some pages of books from the Suwon Library of Seoul National university ▫ 1965, 1967~1968: jpg files capturing pages of books from the Statistics Korea Library ▫ The rest: e-books from the National Archives of Korea

Statistical yearbooks of counties under the control of Jeonnam Province	1961	▫ Mokpo: jpg files capturing pages of books from the Statistics Korea Library
	1964	▫ Muan, Yeocheon, Yeonggwang, Jangheung: jpg files capturing pages of books from the Statistics Korea Library
	1966	▫ Gwangsan, Gwangyang, Damyang, Muan, Suncheon, Yeocheon, Yeonggwang, Wando, Janheung, Jindo, Hampyeong, Haenam: jpg files capturing pages of books from the Statistics Korea Library
The *Gyeongbuk Statistical Yearbook*	1963~1965 1967~1990	▫ 1963, 1964: jpg files capturing pages of books from the Statistics Korea Library ▫ 1967: a pdf file ▫ The rest: e-books in homepage of the National Archives of Korea
Statistical yearbooks of counties under the control of Gyeongbuk Province	1961	▫ Daegu: jpg files capturing pages of books from the National Assembly Library ▫ Pohang: jpg files capturing pages of books from the Statistics Korea Library
	1962	▫ Gyeongsan, Yeongju, Pohang: jpg files capturing pages of books from the Statistics Korea Library
	1966	▫ Gyeongsan, Goryeong, Gunwi, Gimcheon, Dalseong, Bonghwa, Seongju, Andong, Yeongil, Yeongju, Ulleung, Wolseong, Cheongsong: jpg files capturing pages of books from the Statistics Korea Library ▫ Yeongyang: jpg files capturing pages of books from the National Assembly Library
The *Gyeongnam Statistical Yearbook*	1961 1963~1965 1967~1990	▫ 1963: jpg files capturing pages of books from the Suwon Library of Seoul National University ▫ The rest: e-books from the National Archives of Korea
Statistical yearbooks of counties under the control of Gyeongnam Province	1966	▫ Geoje, Geochang, Namhae, Sacheon, Sancheong, UIsan, Changnyeong, Changwon, Chungmu, Hadong, Haman: jpg files capturing pages of books from the Statistics Korea Library
The *Jeju Statistical Yearbook*	1961~1965 1967~1990	▫ 1961, 1963: jpg files capturing pages of books from the Statistics Korea Library ▫ 1962: jpg files capturing pages of books from the Suwon Library of Seoul National University ▫ The rest: e-books from the National Archives of Korea
Statistical yearbooks of counties under the control of Jeju Province	1966	▫ Namjeju, Bukjeju, Jejusi: jpg files capturing pages of books from the Statistics Korea Library

These books provide comprehensive information on the following local statistics presented in figures and tables: (1) short history; (2) land area and climate; (3) population; (4) industry and economy, including agriculture; (5) public employees and finance; (6) water works, health, and cleaning; (7) social welfare; (8) education; (9) public peace; (10) price and national account; (11) communication and electric power; (12) foreign trade and exchange; (13) justice of their territories; and (14) international statistics. Recently published statistical yearbooks provide additional detailed information with improved physical design in statistical figures and tables. However, the basic contents and structure remained unchanged over time. <Table 2-2> provides common variables contained in the statistical yearbooks of various provinces and years. [Figure 2-1] shows the contents of the tables used in Seoul Statistical Yearbook on population and agriculture. [Figure 2-2] is a sample page of 1970 Gyeonggi Statistical Yearbook related to agricultural equipment.

We selectively inputted the statistics on population and agriculture, which are highly crucial for our empirical analyses to construct data on input factors of agriculture by year, province, and county. Country-wide data by year were created by adding province-level data of the same years. <Table 2-3> introduces the variables on agricultural inputs that were used to construct our dataset. The land areas and agricultural inputs are originally reported in various units that were traditionally used in South Korea. We converted these into meter-units that are currently used (see Appendix Table A1 and A2).

We believe that the quality of our data set on agricultural inputs is comparable with that of other historical data. We attempted to determine and correct errors in our sources as much as possible. For example, we crosschecked among different sources providing similar statistics, discovered typos, and differentiated between 0 and missing values. Although constrained by insufficient resources and manpower, the central and local authorities appear to have exerted effort to produce accurate and consistent statistics that were crucial for planning and implementing national and regional policies. At the very least, the records we utilized are the most reliable sources of local agricultural inputs that are currently available.

Table 2-2| Information in Statistical Yearbooks Related to Population and Agriculture

Category	Contents	
Population	▫ Growth of population ▫ House and population by county ▫ Population by sex ▫ Population by age and sex ▫ Population by education level	▫ Population by occupation ▫ Registered foreigner ▫ Movement of population ▫ Population by industry
Agriculture	▫ Number of farm house and farm population ▫ Food grain production: rice, barley and wheat, miscellaneous grains, pulse, potatoes, vegetables, fruits, special crops, medicinal plants, tobacco ▫ Farm environment: agricultural equipment, chemicals, fertilizers, pesticides ▫ Farm disaster ▫ Agricultural economy policy: agricultural cooperative federation, farmland improvements, New Community (Saemaul) Movement, government purchase of food grains	

Figure 2-1| Contents of the 1970 *Gyeonggi Statistical Yearbook*

목 차

Figure 2-1| Sample Table Used for Inputting Data: Part of 1970 *Gyeonggi Statistical Yearbook*

53. 농 기 구

단위 : 대

항목	경운기 계	경운기 경기	경운기 동력경운기	제초기	제충기	분무기 계	분무기 인력	분무기 동력	살분기 계	살분기 인력	살분기 동력
1964	96,309	96,254	55	16,277	38	11,842	11,230	—	6,822	6,822	—
1965	94,473	94,361	112	15,442	48	14,612	14,612	—	8,446	8,446	—
1966	97,016	96,865	151	14,551	55	14,038	14,038	—	8,183	8,183	—
1967	97,088	96,547	541	14,551	54	19,186	19,186	—	7,473	7,473	—
1968	96,590	95,329	761	14,310	34	25,547	25,547	—	6,721	6,721	—
1969	93,582	92,311	1,271	12,823	29	30,897	30,897	—	6,812	6,812	—
인천시	1,405	1,379	26	241	4	1,095	1,095	—	272	272	—
수원시	1,162	1,114	48	—	2	448	448	—	89	89	—
의정부시	243	230	13	—	—	144	144	—	22	22	—
양주군	3,940	3,862	78	542	3	563	563	—	437	437	—
여주군	5,283	5,243	40	1,064	—	1,288	1,288	—	323	323	—
평택군	6,629	6,583	46	584	—	1,447	1,447	—	636	636	—
화성군	13,641	13,534	107	2,425	8	3,420	3,420	—	628	628	—
시흥군	3,081	3,015	66	259	—	1,157	1,157	—	281	281	—
부천군	4,070	3,988	82	—	—	2,017	2,017	—	249	249	—
파주군	3,986	3,883	103	139	2	1,271	1,271	—	405	405	—
고양군	2,256	2,142	114	485	—	1,465	1,465	—	345	345	—
광주군	4,892	4,860	32	579	6	1,851	1,851	—	285	265	—
연천군	2,039	2,005	34	47	—	388	388	—	155	155	—
포천군	2,518	2,478	40	552	1	880	880	—	120	120	—
가평군	1,386	1,384	2	441	—	268	268	—	119	119	—
양평군	5,084	5,039	45	1,266	—	923	923	—	280	280	—
이천군	5,112	5,064	48	628	2	997	997	—	426	426	—
용인군	4,771	4,727	44	945	—	930	930	—	512	512	—
안성군	5,408	5,341	67	1,264	—	2,033	2,033	—	681	681	—
김포군	6,128	5,996	132	247	—	2,609	2,609	—	201	201	—
강화군	9,977	9,876	101	1,074	1	4,590	4,990	—	321	321	—
옹진군	571	568	3	36	—	273	273	—	25	25	—

항목	가마니기계 계	가마니기계 수직	가마니기계 족답	가마니기계 동력	양수기 계	양수기 인력	양수기 동력	농업용원 계 대수	농업용원 계 연마력	원동기 대수	원동기 연마력
1964	77,825	75,285	2,532	8	6,388	4,213	2,175	4,795	61,704	4,158	50,397
1965	73,964	71,336	7,569	9	10,560	4,866	5,694	6,926	75,717	6,440	64,858
1966	69,460	66,895	2,561	4	10,686	4,815	5,871	7,480	81,783	6,945	70,016
1967	65,160	62,190	2,574	26	10,348	4,566	5,782	7,502	8,458	6,967	68,822
1968	63,710	61,218	2,472	20	11,002	4,703	6,299	8,554	77,701	6,004	66,781
1969	60,159	56,929	3,200	30	12,268	5,336	6,532	7,955	93,130	7,412	80,975
인천시	134	58	76	—	76	1	75	197	944	146	623
수원시	270	270	—	—	124	—	124	114	938	96	645
의정부시	10	9	1	—	72	1	71	28	413	22	268
양주군	382	346	36	—	411	—	411	460	5,583	457	5,577
여주군	4,712	4,529	183	—	645	5	640	469	4,703	454	4,413
평택군	6,312	6,202	91	19	1,465	581	884	894	6,537	794	5,550
화성군	9,948	8,885	1,061	2	803	181	622	778	8,904	727	8,100
시흥군	894	871	23	—	339	22	317	278	2,892	256	2,547
부천군	728	642	86	—	1,017	872	145	285	3,156	230	2,312
파주군	944	739	205	—	1,305	772	533	653	6,607	653	6,607
고양군	889	451	435	3	500	157	343	242	4,219	220	2,379
광주군	1,587	1,576	11	—	238	6	232	338	3,662	321	3,401
연천군	163	144	19	—	110	—	110	189	12,448	189	12,448
포천군	342	316	26	—	260	—	260	324	3,376	323	3,346
가평군	562	510	52	—	100	1	99	124	1,748	118	1,598
양평군	4,889	4,817	72	—	213	5	208	309	3,418	301	3,313
이천군	5,431	5,300	131	—	988	451	537	598	3,592	585	3,406
용인군	4,877	4,864	13	—	360	—	360	476	4,619	446	4,014
안성군	5,381	5,343	38	—	611	76	535	594	5,225	564	4,359
김포군	7,014	3,458	550	6	322	158	164	292	6,288	222	2,332
강화군	2,617	7,586	85	—	2,280	2,047	233	288	3,745	273	3,424
옹진군	19	13	6	—	29	—	29	25	313	25	313

자료 : 농산과

Table 2-3| Variables Inputted into Dataset on Input factors of Agriculture

Category	Contents	Unit
Year	▫ Survey year	
Region	▫ Entire nation, names of provinces and counties	
Population	▫ Population by industry - Agriculture, Mining, Manufacturing, Construction, Electricity, Commerce, Transportation, Service, NA	
Agriculture: Chemical fertilizer	▫ Amount of consumption by raw materials - Nitrogen, Phosphoric acid, Potassium	ton
	▫ Amount of consumption by main components - Ammonium sulphate, Ammonium nitrate, Urea, Superphosphate, Triple superphosphate, Phosphate, Mixed, Complex, Potassium sulphate, Ammonium chloride, Nitrogenous, Fused phosphate, Potassium chloride	〃
Agriculture: Fertilizer	▫ Amount of consumption - Compost, Green manure, Native grass, Human manure, Fermented	〃
Agriculture: Pesticide	▫ Amount of consumption by subject of application - Fungicide for paddy rice, Fungicide for gardening, Pesticides for paddy rice, Fungicide for gardening, Herbicide for paddy rice, Herbicide for gardening	〃
	▫ Amount of consumption by formulation - PMA-Hg, PMA, PTAB, Pitamel, Parachion, Buraes, Kasugamycin, Iprobenfos(IBP), Neoasoin, Diazinon, Smithion, Danazione, EPN, Fenthion, PCP, F34, 24D, EM, Maratera, Matetera, Jeilderin, BDM, BHC, DDT75, Marahion, Neo pps, Horitol, Mechilparathion, Echilparathion, Gammadol, Dielderin	〃
Agriculture: Agricultural equipment	▫ Number of possession - Plough, Power tiller, Weeder, Seeder, Spray, Hand spray, Auto spray, Duster, Hand duster, Auto duster, Hand thresher, Ratary thresher, Ratary hand thresher, Ratary auto thresher, Winnower, Hand winnower, Aauto winnower, Straw rope finishing machines, Hand straw rope finishing machines, Auto straw rope finishing machines, Hand straw bag, Foot straw bag, Auto straw bag, Water pump, Hand water pump, Auto water pump, Sower, Prime motor, Electric motor, Rice husker, Rice miller, Auto rice miller, Barley processor, Engine, Flour mill, Noodle making machine, Cotton gin, Scutcher, Rear-car, Tractor	number
Agriculture: Land consolidation	▫ Number of district, Area, Construction expenses	number/ha /1000 won
Agriculture: Land clearance	▫ Number of district, Area, Construction expenses	〃
Agriculture: Land reclamation	▫ Number of district, Area, Construction expenses	〃
Agriculture: Irrigation	▫ Number of district, Area, Construction expenses	〃
Agriculture: Small-scale irrigation	▫ Number of district, Area, Construction expenses	〃
Agriculture: Land Improvement Association	▫ Nunber of association, Number of member, Area	number/number/ha
Agriculture: Agricultural Cooperative Union	▫ Nunber of union, Number of member, investment money	number/number/ 1,000 (Korean) won
Agriculture: Agricultural education club	▫ Farming improvement club - Number of club, Number of member, Number of leader	number/number /number
	▫ Life improvement club - Number of club, Number of member, Number of leader	〃
	▫ 4H club - Number of club, Number of member, Number of leader	〃

Changes in Agricultural Inputs

Introduction of Major Capital Inputs

Unlike land and labor inputs in agriculture that are more or less straightforward, major capital inputs considered in this study need to be explained. Capital inputs consist of fixed capital, such as farm buildings, perennial fruit trees, and reservoirs, and working capital, including purchased fertilizers and pesticides, livestock maintenance costs, and expense for farming tools and machines. According to relevant researches and statistical data about Korean agricultural growth, R&D investment, agricultural extension, high level of education and cooperation of farmers, and large-scale public rural development projects, which is helpful for enhancing quality of agricultural inputs, should also be beneficial for raising agricultural productivity (Ban, 1974; Park, 2002; statistical yearbooks of each Provinces and Districts in Korea). Among these inputs, fertilizers, pesticides, and agricultural machines are said to be the most important inputs which have played key roles in increasing Korean agricultural outputs since 1945. These inputs were able to foster the growth of crops, to prevent insects or epidemic, to kill weeds, or to increase the pace of field work.

1. Fertilizers and Pesticides

According to ‘Setting and Appointing of Official Standards of Commercial Fertilizers’ (Notification No. 2018-3 of the Rural Development Administration), fertilizers are divided into ordinary fertilizers and by-product fertilizers. Ordinary fertilizers include nitrogenous, phosphatic, potassic, composite, lime, silicate, magnesium, and micronutrient fertilizers. By-product fertilizers include fertilizers made from organic materials or soil microbes.

The major functions of the five major fertilizers are as follows (Kim, 2014; Yoon, 2010). First, nitrogen is constituent of amino acid, protein, nucleic acid, and enzymes, so nitrogenous fertilizers have positive effect on growth of plants. Phosphatic fertilizers are involved in growth of fruits and cells. Especially these are effective to pulses, canola, wheat, potato, cucumber, and various fruit trees. Potassic fertilizers can strengthen roots and stems and speed up metabolism. Lime fertilizers boost growth of roots, strengthen resistance to various diseases, and improve physical and chemical quality of soil. Organic fertilizers are made of raw material from animals and plants. These have indirect effects on growth of plants. The first macronutrients of all essential nutrients for growth of plants are nitrogen, phosphoric acid, and potassium. Thus, nitrogenous, phosphatic, and potassic fertilizers may regarded as particularly important types of chemical fertilizer.

Chemical fertilizers were introduced during the Japanese colonial period. In August 1910 inorganic fertilizers made from human excrement were produced for the first time in ammonium sulphate factory in Busan that produced about 130 tons of ammonium sulphate fertilizers per year. The famous Heung-Nam Fertilizer Plant was established in 1930, and remained as the major producer during the colonial period. In 1939, the factory accounted for 90% of domestic gross fertilizer production. The division of South and North Korea after the liberation from the Japanese colonial regime and the massive destructions caused by the Korean War drastically limited the supply of fertilizers. This led Korean Government to decide to propel large-scaled construction of fertilizer plants aimed at food self-sufficiency since 1960. As a consequence, seven government-owned fertilizer companies were established in the 1960s, which was followed by establishment of private fertilizer plants. As the domestic production of fertilizers rapidly increased, South Korea began to export fertilizers from 1967.

Pesticides can be classified into three types according to the purpose of usage, including insecticides, fungicides, and herbicides. Insecticides are used to kill insects, whereas fungicides are used to get rid of viruses or epidemic diseases. The major function of herbicides is to kill weeds.

Chemically-made-pesticides were first used during the Japanese colonial period. Most of them were produced in domestic pesticide companies such as Joseon Nongyak, Joseon Samgong, and Donghae Sireop. Foreign organosynthetic agricultural chemicals were imported and introduced to Korea after the liberation from Japanese colonial regime. For example DDT was first imported in 1949. The major pesticides used in the 1940s and the 1950s include organochlorine insecticides like DDT and HC, organomercurial insecticides such as Ceresin lime, and organophosphorous pesticides such as EPN and parathion.

In 1969 parathion began to be produced in Korea, the first domestically produced among organosynthetic pesticides. Afterwards, many other kinds of agricultural chemicals such as BHC, Diaginon, and Beam were also produced and exported. Since 1949 when 26 kinds of pesticides were permitted to use, the number of pesticides approved increased over time, 364 in the 1950s, 2,867 in the 1960s, 1,554 in the 1970s, and 3,149 in the 1980s. The use of agricultural chemicals, after reaching its peak in 1976, began to decrease in fear of side effects due to toxicity.

2. Agricultural Machines

Agricultural machines can be classified into several categories according to their functions. The first type is machine for management of land that include ridge maker, plow, and rotary. The second type is machine for generating power or transportation including trailer, tractor, loader, motor, and power tiller. The third type is machines for planting rice such as pumping machine, sower, and rice transplanter. The fourth is machine used in growth period that includes sprinkler, power sprayer, and duster. Finally, there are machines that are used in harvest season such as combine, and power thresher. From the Japanese colonial period to the 1950s, stationary agricultural machines and motors were introduced to Korean agriculture. A stationary machine can work only if it is connected with a motor, a power generating machine. These machines were introduced in Korea in the early of 1930s by Japan who wish to increase rice production in Korea. Petroleum 5-horsepower motors were first produced in 1949 by Dae-Dong Company in Korea. The localization of low speed diesel motors had been completed by 1956.

During the 1960s, pumping machine, power tiller, mist and duster were introduced and diffused for dealing with droughts and harmful insects. Korea experienced chronic food shortage in the 1960s, which let the government to make efforts to increase food productions. Droughts and harmful insects were noted as the main causes of low agricultural productivity. Pumping machines, mist and dusters were introduced and supplied to resolve the problems. Power tiller was used for generating power as did motors. It was introduced in Korea in 1959 from Japan. In 1963, power tillers equipped with water cooling petroleum engine was produced and supplied by Dae-Dong Company.

Portable pumping machines with high-speed rotation engines were introduced in 1962 by Japan. After 1963 farmers supplied water with power tiller-connected-portable pumping machines, moving paddy to paddy. In 1965, portable small pumping machines were imported in bulk from Japan in response to heavy drought. By the early 1970s, problems in supplying water to paddies had been greatly reduced except in some areas hit by severe drought thanks to the efforts to supply portable pumping machines, pumps, and hosepipes and to develop groundwater during the late 1960s.

Power mist and dusters were introduced in the early of 1960s from Japan. In 1963 when bailey scab prevailed throughout the country, the government urgently imported 2,172 power mist and dusters and supplied them to farmers. In 1968, Han-Kook-Nong-Gi Inc. partially localized the productions of power mist and duster by making technical cooperation with Japan. Power sprayers were introduced in 1966 from Japan. It could improve farmers’ work efficiency by saving their efforts more than power mist and dusters. In particular, fruit-producing farmers preferred to use it. As a consequence of increased demand, power sprayer began to be produced domestically from 1969. After adopting power mist and dusters and power sprayers it took only 3 hours per 10a to control agricultural pest whereas it took 33 hours to do so by using human-powered-sprayers. In the 1970s farmers could effectively prevent crop failures caused by insects by using these machines.

The major agricultural machines adopted in the 1970s include rice transplanter, binder, combine, and tractor. The demand for labor sharply increases during the seasons for planting and harvesting rice. The labor shortage in these busy seasons became even more serious as farm workers transferred to industrial sectors in the 1970s. Therefore, mechanization of planting and harvesting emerged as a major interest among farmers. Rice transplanters were imported in 1975 by the Agricultural Development Corporation. Binders and combines were imported in 1973 by the Agricultural Development Corporation and the Rural Development Administration. The machines for planting and harvesting started to be supplied to farmers in 1977.

Except for tractor, however, the machines for mechanizing planting and harvest did not affect the Korean agriculture during the period under study. The rice transplanters and various harvest machines could save much time and efforts for planting, harvesting, and threshing. Combine is a systematic machine that can perform threshing, selection, and rapping at the same time. These machines were only gradually diffused because of farmers’ resistance against complicated operation methods, uncertainty, and high prices. In the introductory stage, a few farmers incurred heavy losses due to unskilled operation of those machines. Moreover, binders were unsuitable for harvesting Tong-Il varieties that became popular in 1970s. Mechanization of planting work had been completed in the early 1990s, long after the machines began to be supplied.

Changes in Agricultural Inputs

In this subsection, I present the overall trends of changes and provincial differences in primary agricultural inputs considered in this study. For capital inputs, I focus on three agricultural machines (namely, power tiller, automatic spray, and tractor) and three major components of chemical fertilizer (namely, nitrogen, phosphoric acid, and potassium) that are considered in regression analyses provided in the next section. The reasons for selecting these inputs are explained in section 4. Figures showing the trends of changes and provincial differences in other agricultural inputs are presented in Appendix.

1. Land and Labor

[Figure 3-1] presents how the total planted area of all food crops (measured in billion square meters) changed between 1946 and 1977. The size of land used for crop productions increased and reached the peak in 1965. Afterwards, it declined over time. The total planted area in the late 1970s was similar to that in 1960. During the Korean War (1950 to 1953), the cultivated area temporarily diminished perhaps due to wartime destructions. [Figure 3-2] shows how the area planted with crops differed by province and decade. In the 1960s, the province with the largest planted area was Gyeongbuk, followed by Jeonnam and Gyeongnam. By the 1970s, Jeonnam overtook Gyeongnam at the number one province in terms of the arable land area.

[Figure 3-3] shows the national trend of the area planted with rice (measured in billion square meters). Three features stand out from the result. First, rice-cultivating area accounts for around 40% of the entire arable land in Korea, indicating the importance of the crop. Second, unlike the total planted area, the size of rice-producing area shows an increasing long-term trend. Finally, the temporary drops in the area planted with rice during the Korean War and in the year of 1959 (which was perhaps caused by the Hurricane Sara) was more pronounced than those found for the entire arable lands. [Figure 3-4] presents how the area planted with rice differed by province and decade. Unlike the planted area of all crops, Jeonnam remained the top province for three decades in terms of rice-producing land area.

Figure 3-1| Planted Area of All Food Crops by Year (billion ㎡)

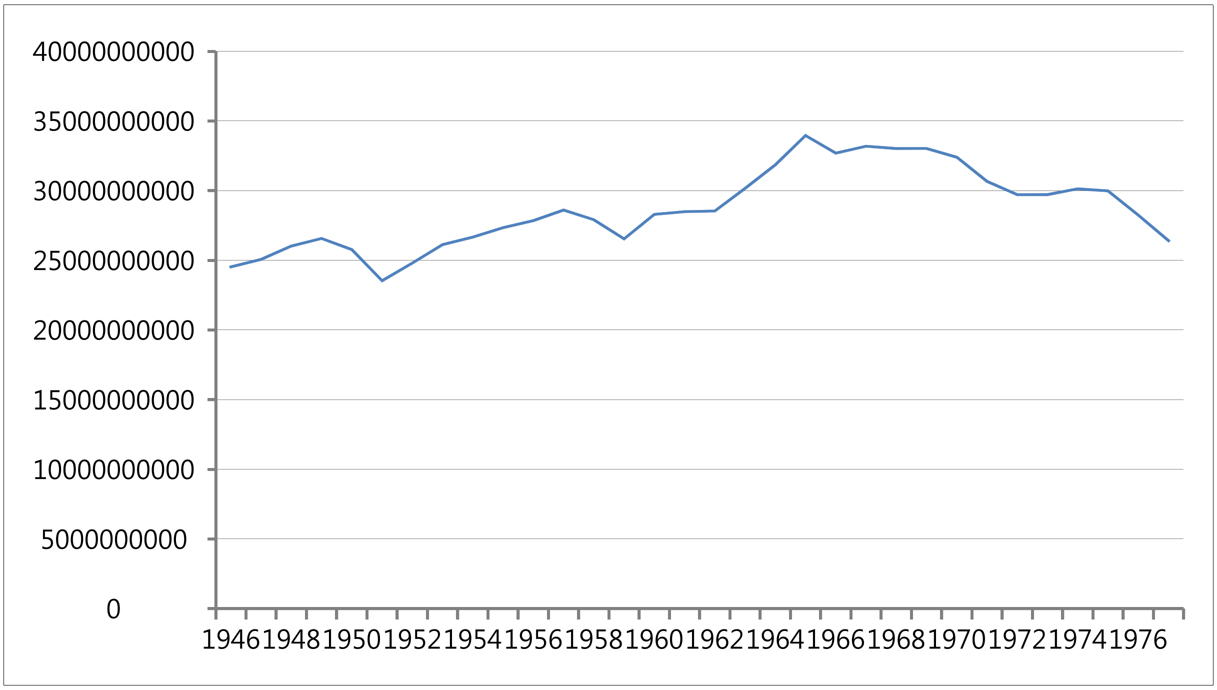


Figure 3-2| Planted Area of All Food Crops by Province/City and Year (million ㎡)

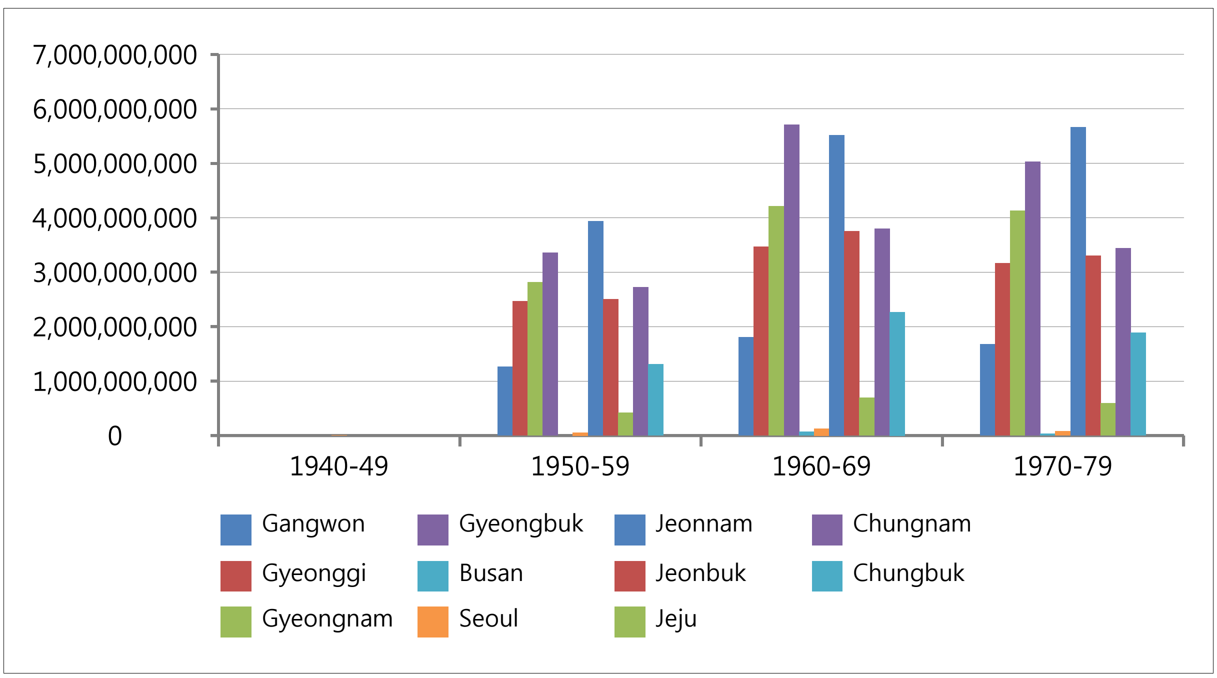


Figure 3-3| Planted Area of Rice by Year (billion ㎡)

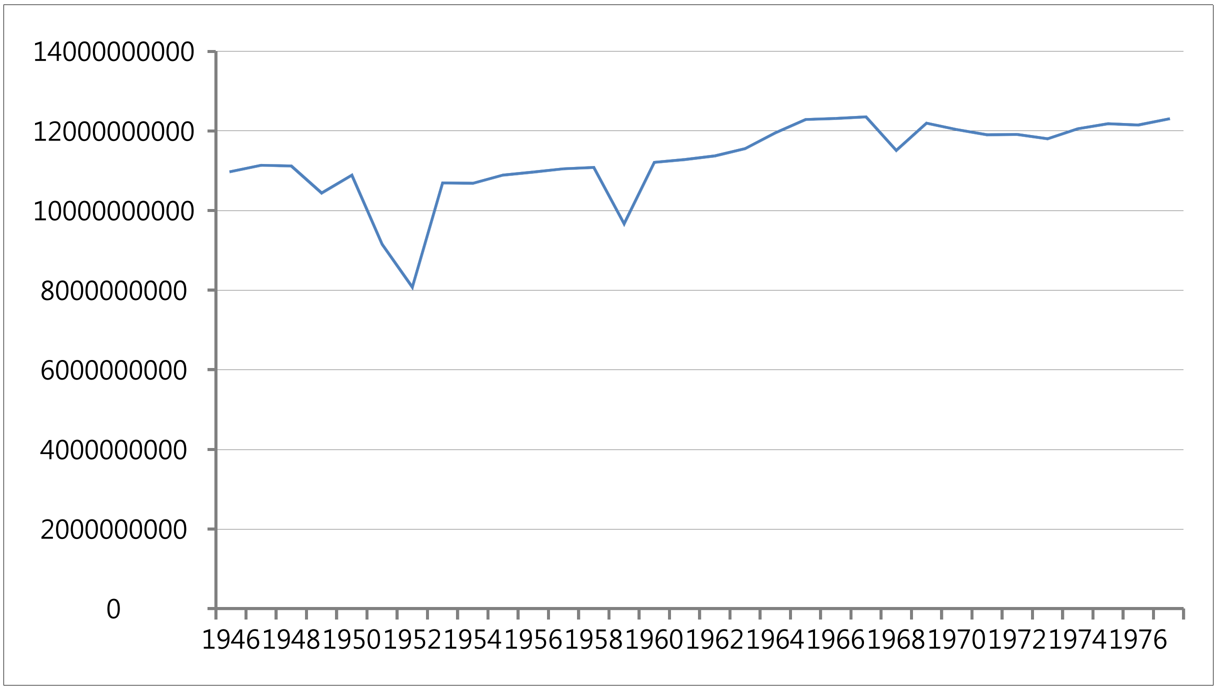
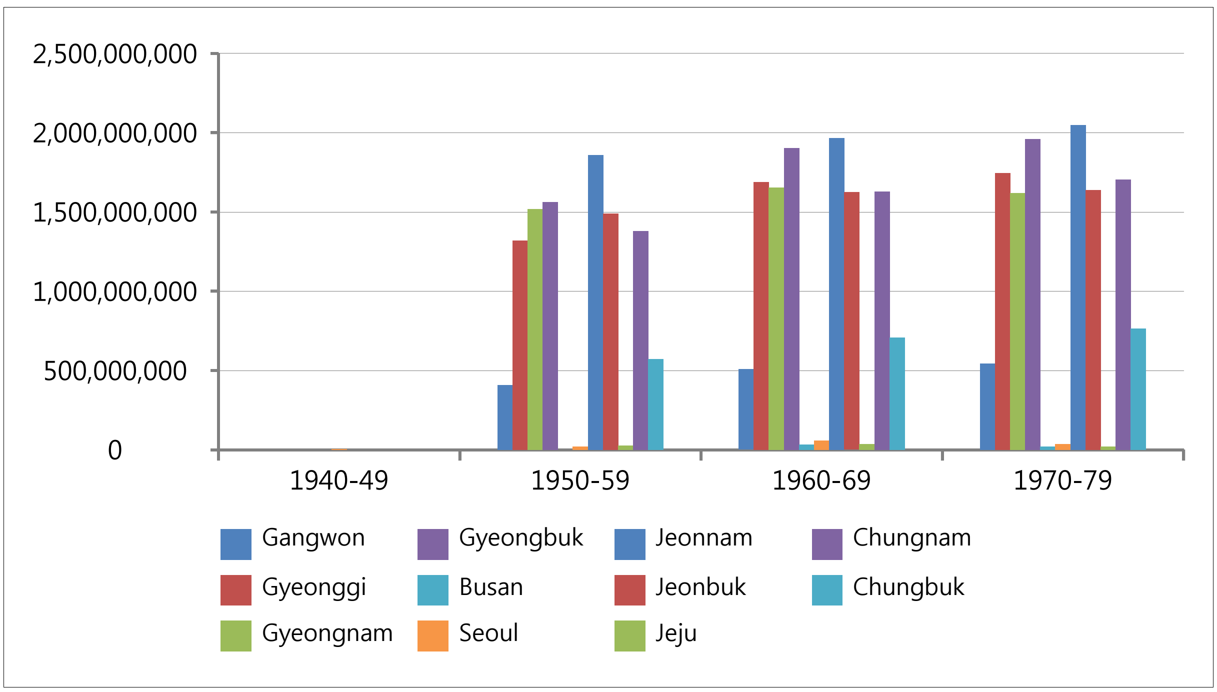


Figure 3-4| Planted Area of Rice by Province/City and Year (million ㎡)



Agricultural labor input may be defined in several different ways. The most restricted definition would be the number of workers employed in agriculture. This will exclude the labor of family members whose contributions would be substantial in the 1960s and 1970s. The most widely defined agricultural labor input would be the entire farm household population. This may incorrectly include fulltime non-agricultural workers living in farm households who were never involved in farming. In addition to these indices of labor inputs, I also use the standardized population living in farm households. More specifically, I converted the total farm household population into the number of adult male equivalent population to obtain a standardized number of farm population. For the conversion, I used age- and gender-specific daily requirement for total calories (reported in Appendix Table) computed by Fogel (1986). The rationale behind this method is that a high work effort is associated with a larger energy consumption.

[Figure 3-5] shows the trend of total farm household population from 1949 to 1977. The farm population sharply fell from 1949 to 1951 as a consequence of wartime deaths. After the Korean War, the farm population gradually increased until 1967, and then declined over time thereafter. [Figure 3-6] presents the total farm population by province/city and by decade. For all four decades, the top three provinces in terms of the size of farm population were Jeonnam, Gyeongbuk, and Gyeongnam, respectively. [Figures 3-7] and [Figures 3-8] provide the national and provincial numbers of standardized farm populations. The results suggest that the standardization according to age and gender compositions do not change much the overall trend and regional differences in the size of farm population.

Figure 3-5| Total Farm Population by Year (million persons)

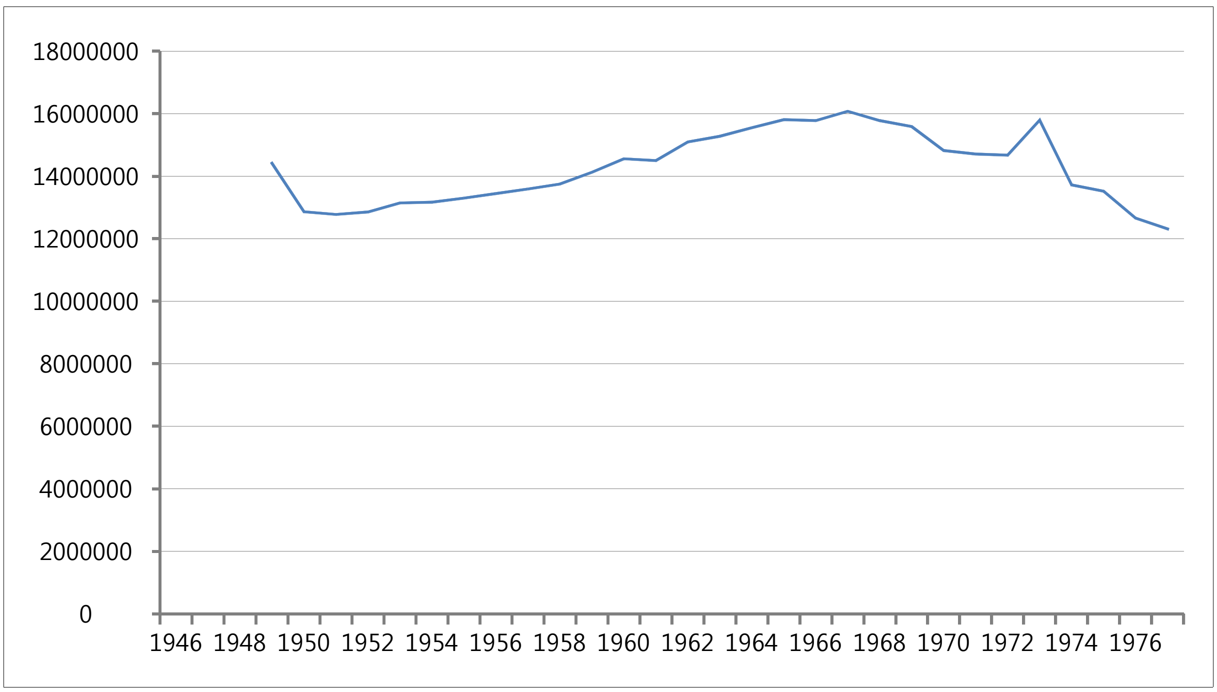


Figure 3-6| Farm Population by Province/City and Year (1,000 persons)

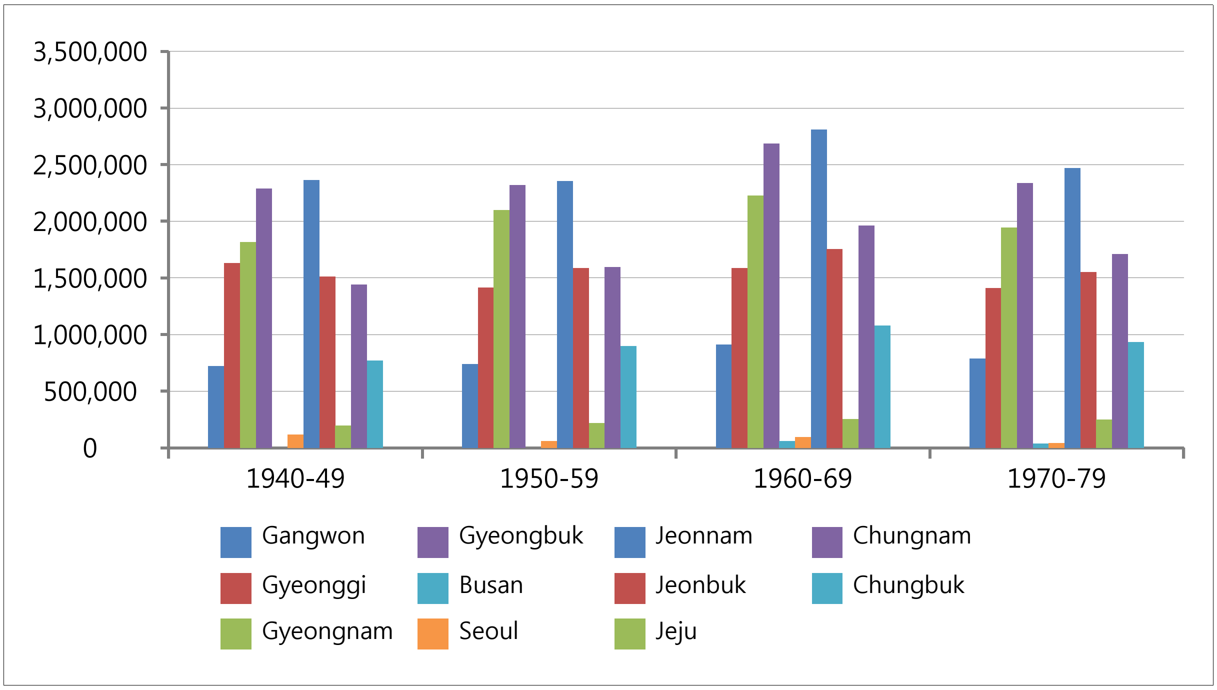


Figure 3-7| Standardized Farm Population by Year (million persons)

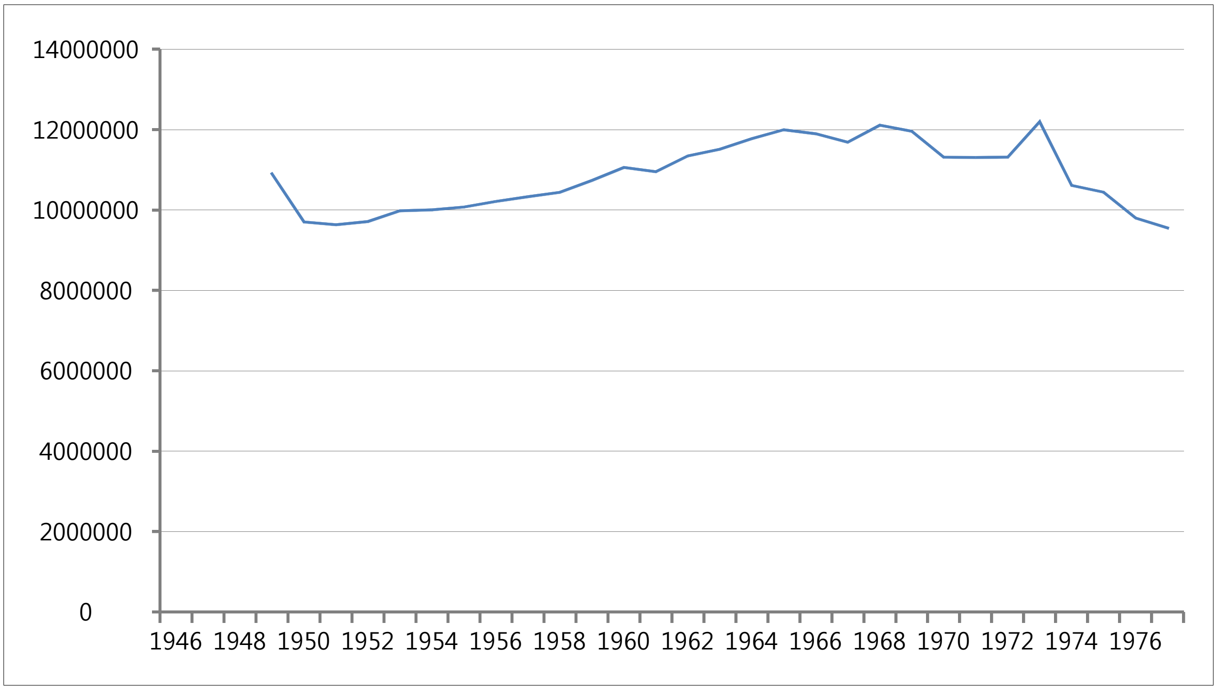
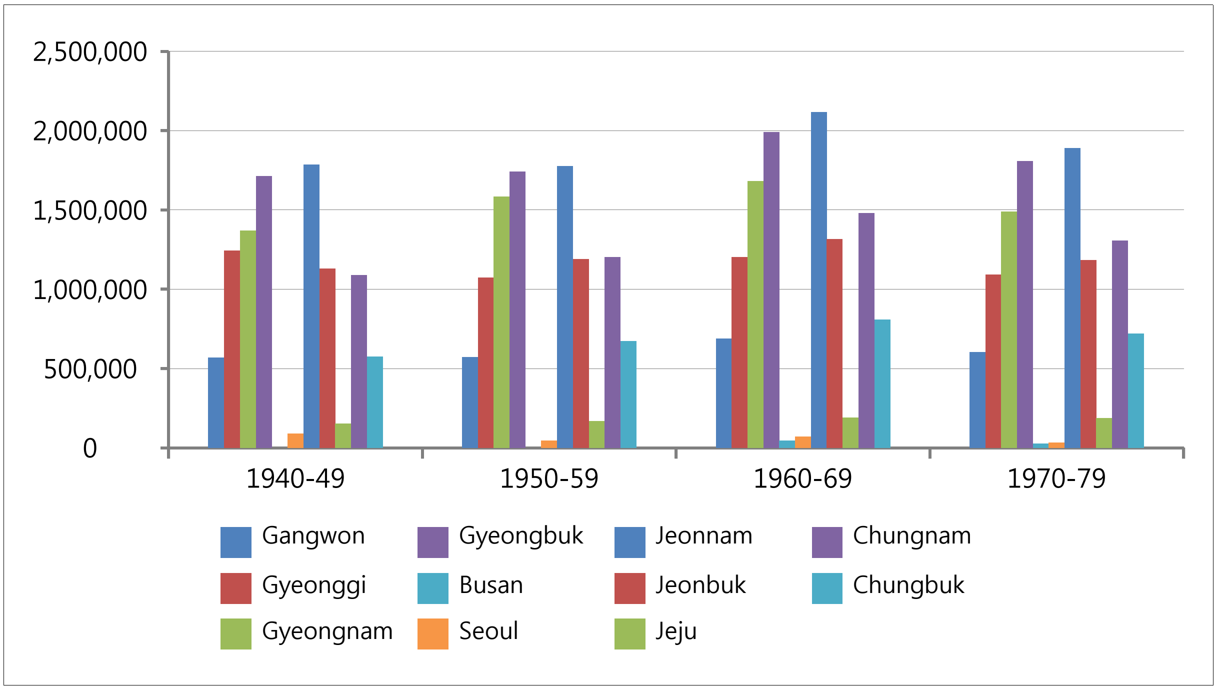


Figure 3-8| Standardized Farm Population by Province/City and Year (1,000 persons)



2. Capital: Agricultural Machines and Chemical Fertilizers

[Figure 3-9] depicts the national trends of the numbers of three agricultural machines. The results indicate that the use of agricultural machines increased sharply from the early 1970s. However, it should be cautiously interpreted because the relatively small number of machines in the early 1960s could result from the larger number of missing observations. For example, the number of counties that reported the number of power tiller is less than 100 until 1963 but increased from 116 in 1967 to 202 in 1980. It is not entirely clear if missing information actually means no machines. Nevertheless, it seems evident that the availability of agricultural machines increased over time, although we cannot be sure how much under-reporting affects the real trend. If we compare years 1969 and 1980 when the number of counties with the number of machines reported remained unchanged, the number of power tillers increased more than 30 times. The increasing trend is similar to those of auto sprays and tractors.

[Figure 3-10] compares the trends of three machines across provinces. The results suggest that the patterns of changes substantially differed by region. For example, Gyeongbuk province experienced the sharpest increase in the number of power tillers, but fell behind other provinces in the supply of auto spray and tractor. Chungnam province and Chungbuk province show particularly rapid increases in the number of auto sprays, whereas Gyeonggi province gained a relatively larger increase in the number of tractor.

Figure 3-9| Number of Three Major Agricultural Machines by Year

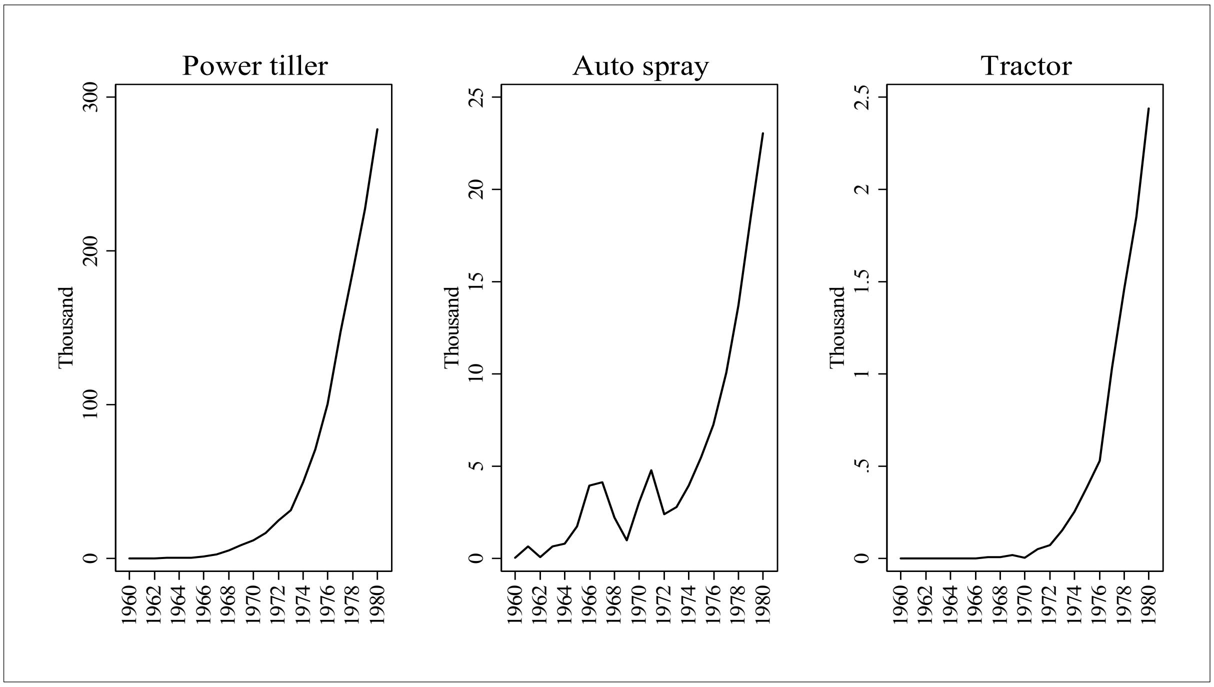


Figure 3-10| Number of Three Major Agricultural Machines by Province/City and Year

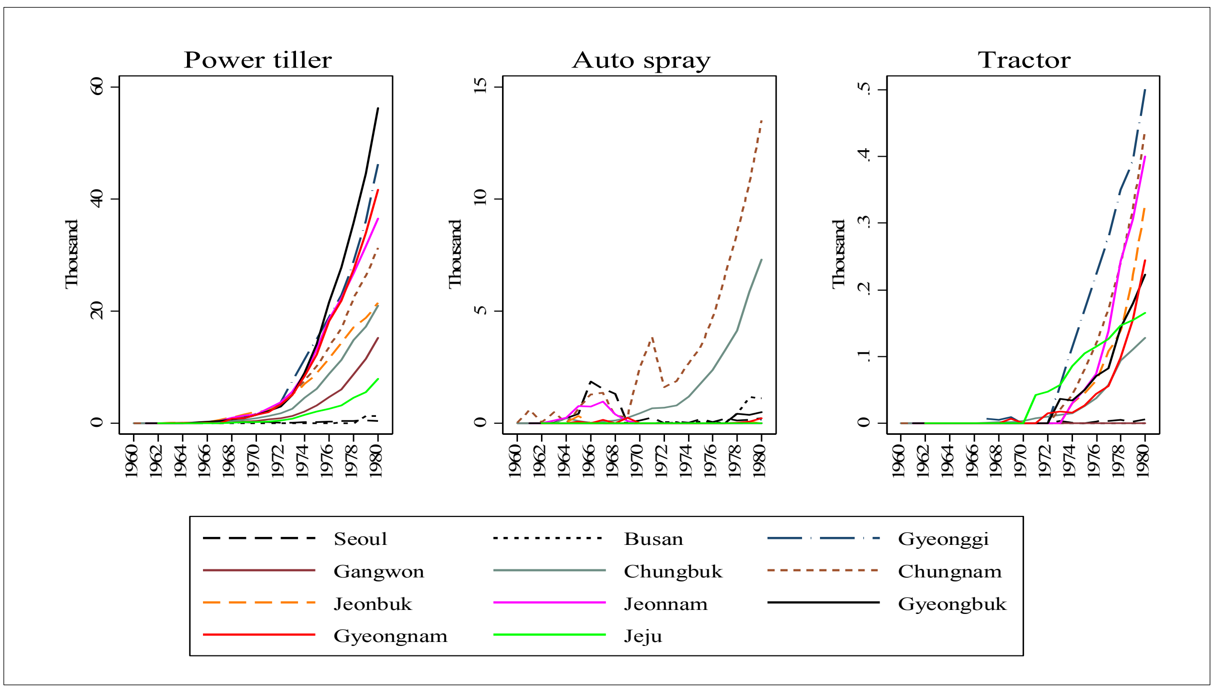
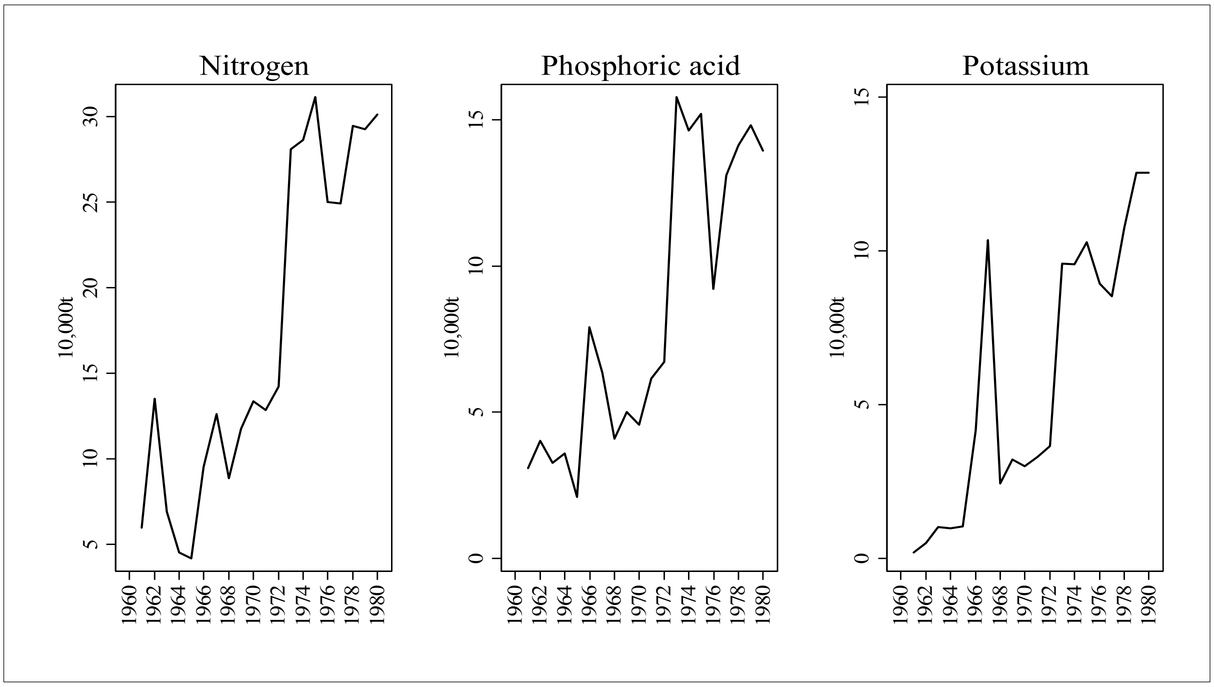


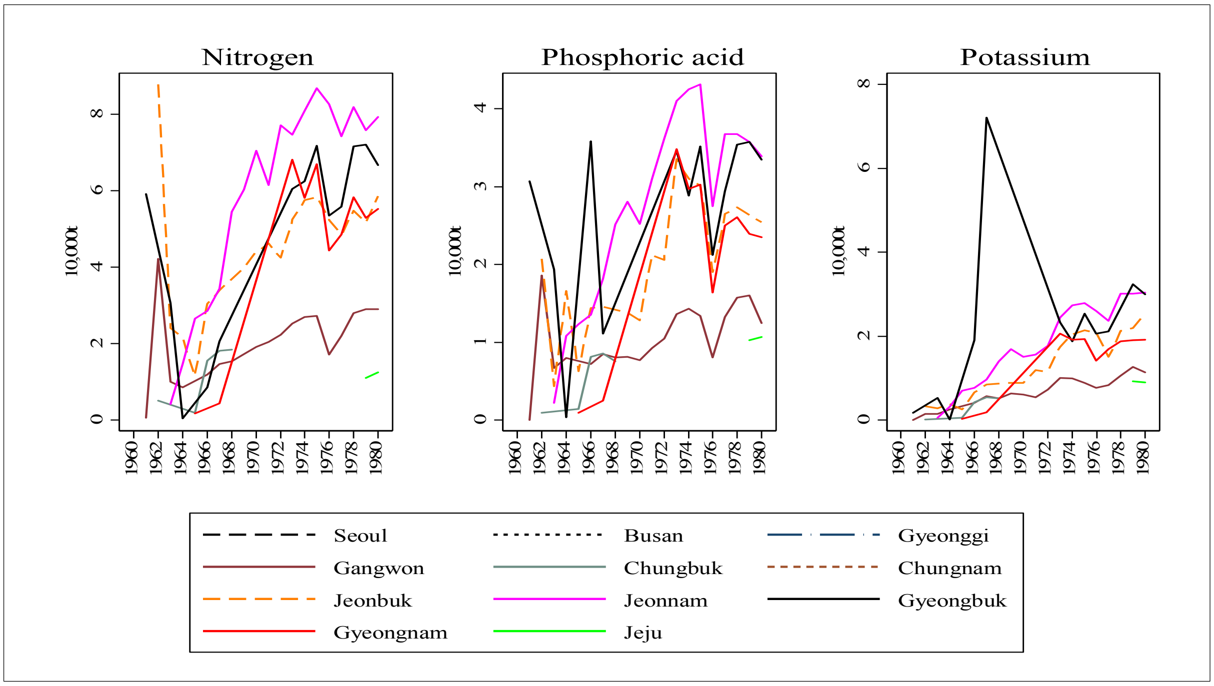
Figure 3-11| Amount of Three Major Components of Chemical Fertilizer Used by Year



[Figure 3-11] shows the national trend of the county consumption of each type of chemical fertilizers. As in the case of agricultural machines, the use of chemical fertilizers dramatically increased from the early 1970s. Again, however, the trends should be taken cautiously because there were more counties in the 1960s where fertilizer consumption is unreported. For example, the average number of counties that reported the consumption of chemical fertilizers is less than 40 during the years from 1960 to 1965; it increases to over 100 counties ten years later. To address such potential problems, I also examined the yearly consumption divided by the number of counties (i.e., the average consumption per county). The results indicate that the rapid increasing trend largely captures the increase in the number of counties reporting fertilizer consumption. The average consumption of nitrogen increased from 1,842 tons during the 1960s to 2,646 tons during the 1970s; from 857 tons to 1,291 tons for phosphoric acid, and 412 tons to 907 tons for potassium, respectively.

[Figure 3-12] provides the amount of use of the three components of fertilizer by province and decade. The figure shows that Seoul, Busan, Gyeonggi, Chungbuk, Chungnam, and Jeju had no or only a few records of chemical fertilizer consumption. Additional investigations are required to determine whether if farmers in these regions actually did not use chemical fertilizers. Another alarming sign regarding the accuracy of the data is that there were large fluctuations in chemical fertilizers consumptions during the period under study. For example, Gyeongbuk province shows an idiosyncratic increase of potassium consumption in 1967. For these reasons, it appears that samples with information on fertilizers should be selected so that variables for chemical fertilizers can be considered in the estimation of agricultural production functions.

Figure 3-12| Amount of Three Major Components of Chemical Fertilizer Used by Province/City and Year



Estimation of Agricultural Production Function

In this section, I estimate production functions of agricultural outputs based on the county-level data on farm outputs and inputs introduced in the preceding sections. As the first step, I focus on the production of rice, the most important crop in Korean agriculture. Estimating the production of overall agricultural outputs will involve weighting of each product. Thus, I will have to collect detailed agricultural prices data for the period under study. Even if such data are available, it is not entirely clear if those prices actually convey actual market prices given the heavy government regulations of farm prices at the time. I will remain these tasks as future research agenda.

Methods

I employ a simple Cobb-Douglas production function given as follows:

$$Q_{it} = A_{it} T_{it}^{\alpha} L_{it}^{\beta} K_{it}^{\gamma} \quad (1)$$

In equation (1), subscripts i and t denote county and year, respectively, Q rice production, A total factor productivity, T land acreage, L labor, and K capital. The regression equation for rice production is provided in equation (2).

$$\ln(Q_{it}) = \ln(A_{it}) + \alpha\ln(T_{it}) + \beta\ln(L_{it}) + \gamma\ln(K_{it}) + \varepsilon_{it} \quad (2)$$

Table 4-1| Definition of Variable

Variable	Definition
Output	Rice output (in 1,000 tons)
Land	Rice cultivation area (in
Labor	Standardized population (number of adult male equivalent population) in rice cultivating farm households
Agricultural Machine	
Power tiller	Number of power tillers
Auto spray	Number of auto sprays
Tractor	Number of tractors
Machine	Number of three major agricultural machineries weighted by price
Chemical fertilizer	
Nitrogen	Amount of nitrogenous chemical fertilizer used (in tons)
Phosphoric	Amount of phosphoric acid chemical fertilizer used (in tons)
Potassium	Amount of potassium chemical fertilizer used (in tons)
Fertilizer	Amount of three major components of chemical fertilizer (in tons)

Output and input variables used in the regressions are defined in <Table 4-1>. The variable on output is defined as the total amount of rice produced in a county in a given year (measured in ton). The variable pertaining to land input is defined as the size the rice-cultivating area (measured in hectare) in each county in a given year. For labor input, I use the standardized population living in farm households cultivating rice for the following reasons. First, family members were an important source of labor input in agriculture in Korea in the 1960s and 1970s that was characterized by small-scale independent farming. Thus, including only agricultural labor force may underestimate the actual size of labor input. Secondly, the effective contribution of each type of family members to farm productions should differ by age and gender. Thus, I converted the total farm household population into the number of adult male equivalent population to obtain a standardized number of farm population. For the conversion, I used age- and gender-specific daily requirement for total calories (reported in Appendix Table) computed by Fogel (1986). The rationale behind this method is that a high work effort is associated with a larger energy consumption.

As noted in the preceding sections, variables pertaining to capital inputs are not universally reported in provincial or county Annual Statistics. Therefore, there is a tradeoff between considering more variables on inputs and additional loss of observations. I attempt to circumvent this problem in the following two ways. Firstly, I first estimate an agricultural production function excluding the variable on capital inputs, and then extend the model by including additional capital inputs to examine the effects of the sample selections arising from missing observations of capital inputs. Secondly, I only focus only on major components of capital inputs to achieve a balance between omitted variables and missed observations.

For agricultural machine, I consider power tiller, auto spray, and tractor. These three agricultural machineries were most widely used capital inputs that strongly influenced agricultural productivity in the 1960s and 1970s. The number of each of these machines is reported for at least 3640 county-year observations. Furthermore, these three were the most expensive farm machineries. The most expensive machine was tractor of which price was 4.6 million won in 1980. The second and third most expensive ones were power tiller and autos pray that were priced 1.1 million Won and 0.4 million won in 1980, respectively. Other agricultural machines widely used in 1960s and 1970s, such as automatic water pumps and automatic dusters, were relatively cheap (less than 0.2 million Won). In addition to these three individual machines, I constructed and used a composite index of capital input (Machine) by computing weighted averages of three machines using their relative prices as weights.

Similarly, I considered three major components of chemical fertilizer in the analysis, namely, the amount of nitrogen, phosphoric acid, and potassium used in each county and year. Each of these inputs is reported for at least 3,500 county-year observations. It appears that other types of chemical fertilizer reported in data contain the three major components. In addition to including these three components of chemical fertilizer, I constructed and used a composite index of capital input (Fertilizer) by adding up the amounts of the three individual inputs. The unit price of each component of chemical fertilizer is unavailable. However, the prices of different products of chemical fertilizers that contain each of the three components were similar in the 1960s and 1970s. Thus, I applied equal weights for computing the composite index.

In constructing data on agricultural inputs, I treated zero and missing observation differently. In case of newly introduced agricultural machinery, however, it is not fully straightforward to distinguish between no machine and missing observation. For example, it appears that tractor was being introduced in the late 1960s. Thus, it is likely that the number of tractors was not reported in counties where it had not been introduced. For the reason, I adjusted sample selection in the following manner. For the counties where at least one of the three major agricultural machines is reported, missing values of the other machine(s) were regarded as no machines. Since the three selected machines are all important and expensive inputs, it is less likely one was neglected whereas the other was reported in the Annual Statistics.

Table 4-2| Summary Statistics by Selected Sample

	(1) Land & labor available	(2) Land, labor, & machinery available	(3) Land, labor, and fertilizer available
ln(Output)	9.4118 (1.3532)	9.4094 (1.4031)	9.6073 (1.1041)
ln(Land)	6.0213 (1.2698)	5.9847 (1.3174)	6.1609 (1.0143)
ln(Labor)	10.2920 (1.3143)	10.2258 (1.4015)	10.4146 (1.0104)
Agricultural Machine			
ln(Powertiller)		3.5344 (2.2742)	
ln(Autospray)		0.8661 (1.7095)	
ln(Tractor)		0.2401 (0.6637)	
ln(Machine)			
Chemical fertilizer			
ln(Nitro)			7.2044 (1.2702)
ln(Phosph)			6.5198 (1.2348)
ln(Potass)			6.0069 (1.3043)
ln(Fertilizer)			7.8144 (1.3408)
N	3015	1984	1017

<Table 4-2> presents summary statistics (mean and standard deviation) of the variables used in regression analyses for three samples selected to the availability of key variables on agricultural inputs. The number of observations with non-missing values of output, labor, and land is 3,015 (Column 1). The sample size diminishes by one third if it is limited to counties and years in which information on agricultural machinery is provided (Column 2). The averages of rice production, land, and labor are not much different between the two samples. If chemical fertilizers are to be considered, the sample reduces to just over 1,000 county-year observations (Column 3). Comparisons of the sample means show that the selected sample has relatively large values of rice production, land areas, and labor input.

Results

Before conducting regressions, I graphically present the relationship between the amount of rice production and three key agricultural input variables. <Figure 4.1> shows a very tight relationship between the size of rice cultivating area and rice production. This suggests that land input is perhaps the most important determinant of agricultural production in Korea during the period under study. Similarly, the standardized rice-producing farm population is closely associated with the amount of rice production,

Figure 4-1| Logarithms of Rice Cultivating Area and Rice Production

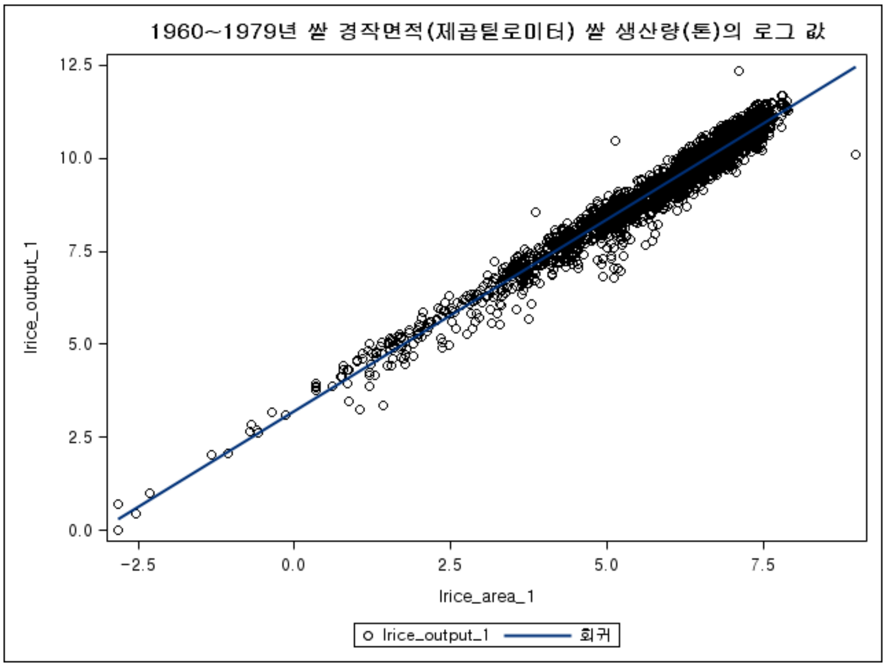


Figure 4-2| Logarithms of Standardized Rice Farm Population and Rice Production

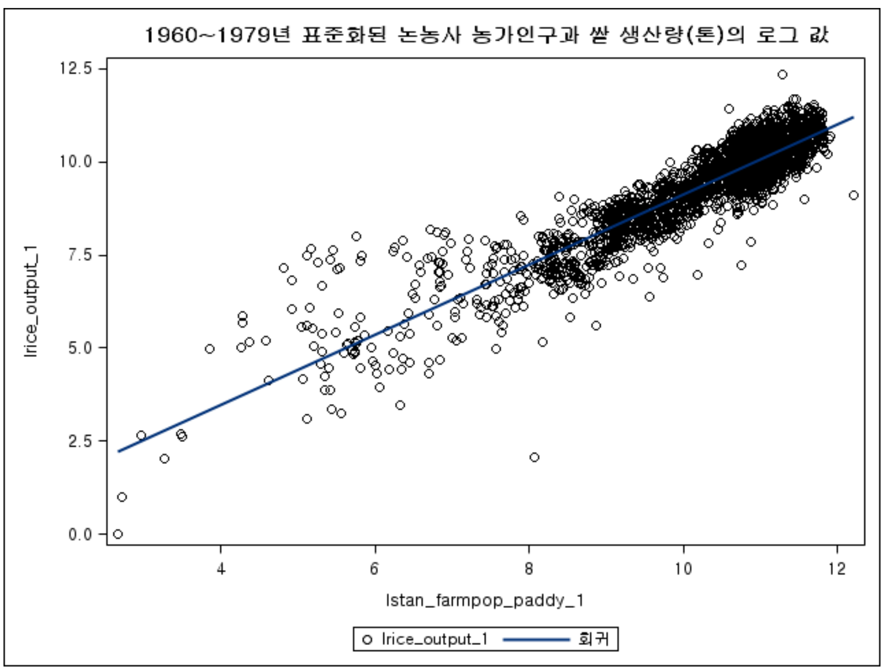
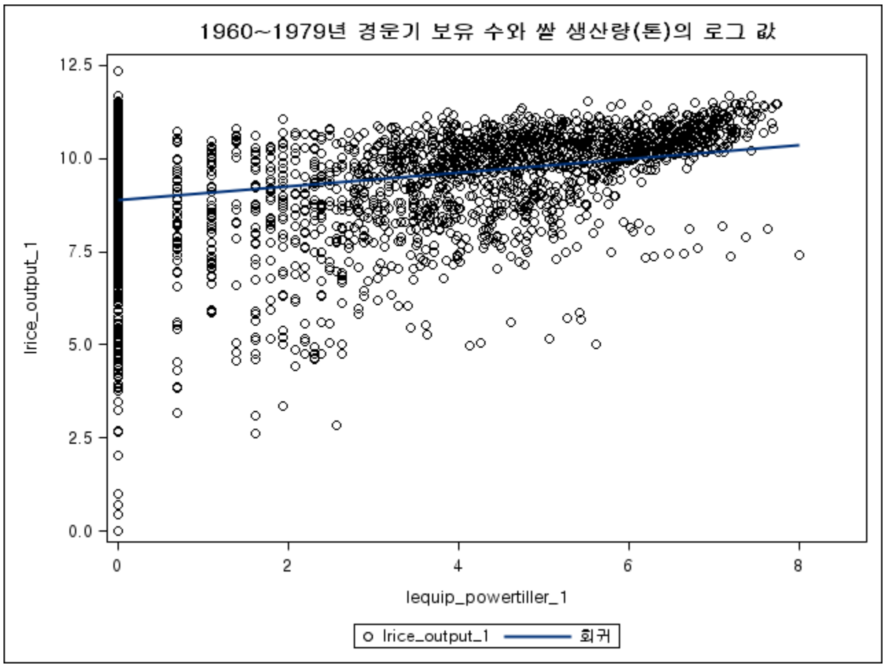


Figure 4-3| Logarithms of Number of Power Tillers and Rice Production



although the relationship is not as tight as that between land area and agricultural output (see Figure 4.2). Finally <Figure 4.3> shows that the number of power tillers, the most widely used agricultural machinery at the time, is only loosely related to rice production.

<Table 4-3> provides the results of OLS regressions in which only land and labor inputs are included as independent variables. The largest sample (N=3,015) is used for the analysis. As [Figures 4-1] and [Figures 4-2] suggest, land and labor inputs have strong positive relationship with the amount of rice production. In particular, the size of land input alone explains more than 95% of variations in rice productions across counties and years (Column 1). If included separately, difference in labor input account for 83% of variations in rice outputs across counties and years (Column 2). If the two inputs are included at the same time, the coefficient for land (0.99) is estimated much larger in magnitude than that for labor (0.05), confirming the huge importance of land in rice production in the 1960s and 1970s (Column 3).

In Model 4, year dummy variables are additionally included to examine how each input contributed to rice output within each year (Column 4). If the year fixed is controlled, the coefficient for land diminishes by about 0.1 whereas the coefficient for labor increases by roughly the same magnitude. It is likely that year fixed effect captures the contributions of omitted factors that changed over time, including increased capital inputs and technical progress. The regression results imply that such omitted factors are positively related to land input, and negatively related to labor input. This is consistent with the fact that labor input decreased more rapidly than land input during the period under study.

Table 4-3| OLS Regression Result: Estimating of Rice Production Function with Land and Labor

Variable	(1)	(2)	(3)	(4)
Intercept	3.14087** (0.0260)	-0.2679*** (0.0792)	2.9213*** (0.0559)	2.444*** (0.0382)
Ln(Land)	1.0401*** (0.0042)		0.9916*** (0.0114)	0.8935*** (0.0070)
Ln(Labor)		0.9405*** (0.0076)	0.0505*** (0.0110)	0.1476*** (0.0068)
Year dummy	No	No	No	Yes
Adj. R-square	0.9526	0.8343	0.9529	0.9833
F-value	60608.2***	15181.0***	30516.9***	8433.2***
N	3015	3015	3015	3015

Significance: * 10%, ** 5%, *** 1%.

<Table 4-4> presents the results of OLS regressions in which a measure of capital input (the weighted average of the numbers of three major agricultural machines) is included along with land and labor inputs. The sample is restricted to 1,984 county-year observations for which the variables on agricultural machinery are available. In the first model (Column 1), only land and labor inputs are included to see how the change in sample affects the result. The estimated coefficients for land and labor obtained from the full and reduced samples (Column 3 in <Table 4-3> and Column 1 in <Table 4-4>) are not much different. This result and similar summary statistics of the two samples (Table 4-2) indicates that the effect of the sample selection is probably modest.

If included separately, the coefficient for machine is positive and statistically significant (Column 2). However, as anticipated from the results reported in [Figure 4-3], the additional input explains only 3% of the variations in rice production across counties and years. If machine is additionally included, the coefficients for land and labor do not change much (Column 3). The estimated coefficient for machine (0.0653) is slightly smaller than that for labor input (0.0812). Inclusion of year fixed effect reduces the coefficients for land and machine, whereas the contribution of labor becomes larger in magnitude. In particular, the coefficient for machine diminishes by more than two thirds. This indicates that the estimated contribution of agricultural machinery largely captures the changes in capital input and output across times.

Similar regressions were conducted with each type of agricultural machine included one by one instead of the composite index of capital input (Table 4-5). Each of the three major agricultural machines has a significant positive effect on the amount of rice output. Inclusion of additional machine(s) does not change the coefficients for the other inputs. For instance, the coefficients for land, labor, and power tiller remain little changed across Models 1 to 3. Adding year fixed effect reduces the magnitudes of the coefficients for power tiller and tractor, as it does to the coefficient for machine as a whole (Table 4-4). However, the coefficient for auto spray is unaffected by controlling year fixed effect.

Table 4-4| OLS Regression Result: Estimating of Rice Production Function with Land, Labor, and Machine

Variable	(1)	(2)	(3)	(4)
Intercept	2.8580***	9.3304***	2.8438***	2.2415***
	(0.0614)	(0.0325)	(0.0591)	(0.0495)
Ln(Land)	0.9703***		0.9541***	0.8840***
	(0.0133)		(0.0128)	(0.0082)
Ln(Labor)	0.0728***		0.0812***	0.1519***
	(0.0125)		(0.0120)	(0.0077)
Ln(Machine)		0.2071***	0.0653***	0.0182***
		(0.0253)	(0.0051)	(0.0034)
Year dummy	No	No	No	Yes
Adj. R-square	0.9584	0.0328	0.9617	0.9849
F-value	22816.7***	67.2***	16524.6***	5884.0***
N	1984	1984	1984	1984

Significance: * 10%, ** 5%, *** 1%.

Table 4-5| OLS Regression Result: Estimating of Rice Production Function with Land, Labor, and Each Type of Machine

Variable	(1)	(2)	(3)	(4)
Intercept	2.4672*** (0.0450)	2.4720*** (0.0448)	2.4298*** (0.0462)	2.2717*** (0.0520)
Ln(Land)	0.8154*** (0.0102)	0.8142*** (0.0101)	0.8054*** (0.0104)	0.8668*** (0.0095)
Ln(Labor)	0.1681*** (0.0092)	0.1677*** (0.0092)	0.1777*** (0.0096)	0.1586*** (0.0083)
Ln(Powertiller)	0.0969*** (0.0022)	0.0962*** (0.0022)	0.0925*** (0.0025)	0.0182*** (0.0047)
Ln(Autospray)		0.0115*** (0.0027)	0.0102*** (0.0027)	0.0101*** (0.0024)
Ln(Tractor)			0.0299*** (0.0083)	0.0020 (0.0079)
Year dummy	No	No	No	Yes
Adj. R-square	0.9786	0.9788	0.9658	0.9850
F-value	30195.7***	22843.0***	25509.3***	5416.9***
N	1984	1984	1984	1984

Significance: * 10%, ** 5%, *** 1%.

<Table 4-6> shows the results of OLS regressions in which an alternative measure of capital input (the average of the amounts of three components of chemical fertilizer) is included along with land and labor inputs. The sample is restricted to 1,017 county-year observations for which the variables on chemical fertilizer are available. In the first model (Column 1), only land and labor inputs are included to see how the change in sample affects the result. The estimated coefficients for land and labor obtained from the full and reduced samples (Column 3 in <Table 4-3> and Column 1 in <Table 4-6>) are significantly different. The coefficient for land increased much, and the effect of labor turned to negative. This confirms the notable different summary statistics of the two samples (Table 4-2), and indicates that the selected sample may not represent the entire country.

If included separately, the coefficient for fertilizer is positive and statistically significant (Column 2). The additional input explains about 45% of the variations in rice production across counties and years, which is much higher than machine input does. If fertilizer is additionally included, the coefficients for land and labor do not change much (Column 3). The estimated coefficient for fertilizer (0.0257) is smaller than that of machine (0.0653) reported in Column 3 of <Table 4-4>. Inclusion of year fixed effect changes the coefficient for fertilizer to negative and statistically insignificant. This indicates that the estimated effect of fertilizer largely captures the changes in capital input and output across times.

I conduct similar regressions in which each component of chemical fertilizer is included one by one in place of the composite index of fertilizer (Table 4-7). Among the three, only potassium has a consistently positive effect on rice production. Nitrogen has a significant positive effect only if other components are not included (Column 1). Inclusion of additional fertilizer(s) does not change the coefficients for land. On the other hand, the negative effect of labor input becomes insignificant if potassium is included in the regression. Adding year fixed effect changes the sign of the coefficient for labor from negative to positive, and reduces the magnitude of the coefficient for potassium.

The results of regression analyses suggest that local agricultural production in Korea during the period from 1960 to 1979 was largely determined by land and labor inputs. Changes in these two factors explain more than 95% of variations in rice production across counties and years. It is difficult to estimate accurately the contributions of capital inputs to agricultural production because data are available only for selected capital inputs and for selected places and years. The results based on using three major agricultural machines of the time (power tillers, automatic sprays, and tractors) suggest that capital inputs also played significant roles in changing agricultural production, especially across times. Given the currently available county-level data on agricultural inputs, it would be reasonable to use the number of major agricultural machines as an index of capital input in estimating agricultural production function.

Table 4-6| OLS Regression Result: Estimating of Rice Production Function with Land, Labor, and Chemical Fertilizer

Variable	(1)	(2)	(3)	(4)
Intercept	3.6144*** (0.1284)	5.2809*** (0.1517)	3.4869*** (0.1344)	2.7585*** (0.1038)
Ln(Land)	1.1645*** (0.0257)		1.1279*** (0.0282)	1.0018*** (0.0179)
Ln(Labor)	-0.1135*** (0.0258)		-0.0989*** (0.0261)	0.0378*** (0.0169)
Ln(Fertilizer)		0.5537*** (0.0191)	0.0257*** (0.0083)	-0.0070 (0.0055)
Year dummy	No	No	No	Yes
Adj. R-square	0.9444	0.4521	0.9448	0.9797
F-value	8621.0***	837.3***	5799.1***	2582.0***
N	1017	1017	1017	1017

Significance: * 10%, ** 5%, *** 1%.

Table 4-7| OLS Regression Result: Estimating of Rice Production Function with Land, Labor, and Each Type of Fertilizer

Variable	(1)	(2)	(3)	(4)
Intercept	3.5243*** (0.1325)	3.5206*** (0.1326)	3.2085*** (0.1249)	2.8025*** (0.1074)
Ln(Land)	1.1325*** (0.0283)	1.1302*** (0.0284)	1.0223*** (0.0275)	1.0017*** (0.0185)
Ln(Labor)	-0.1028*** (0.0260)	-0.1022*** (0.0260)	-0.0192 (0.0249)	0.0406*** (0.0167)
Ln(Nitro)	0.0246*** (0.0093)	0.0145 (0.0146)	-0.0209 (0.0138)	-0.0142 (0.0112)
Ln(Phosph)		0.0129 (0.0144)	-0.0702*** (0.0147)	-0.0144 (0.0109)
Ln(Potass)			0.1518*** (0.0115)	0.0191* (0.0111)
Year dummy	No	No	No	Yes
Adj. R-square	0.9447	0.9447	0.9527	0.9798
F-value	5783.7***	4337.1***	4089.2***	2344.4***
N	1017	1017	1017	1017

Significance: * 10%, ** 5%, *** 1%.

Conclusion

Since the liberation from the Japanese occupation in 1945, South Korea has achieved substantial improvement in the nutritional status of the population, as indicated by the increase in adult heights. Recent studies suggest that increase in local food availability was an important contributing factor of the increased heights of the individuals born prior to 1960. Besides its significance as a long-term factor of improvement in nutritional status, measuring agricultural productivity and determining its major factors in the 1960s and 1970s is an important issue in its own right given the relative size of the Korean agricultural sector at the time. However, in-depth studies on agricultural productions in the past are restricted by the shortage of micro-level data covering the periods prior the 1980s.

In this study, I collected data sources (statistical yearbooks published by each province and county) and constructed databased containing variables regarding major inputs of agricultural productions in the 1960s and 1970s. I examined how major agricultural inputs (including land, labor, agricultural machines, and chemical fertilizers) changed over time and across provinces. By linking the data on inputs with the county-level agricultural production data, I also estimated agricultural production functions, focusing on the production of rice, the most important crop in Korean agriculture.

The present study is distinct from previous studies on Korean agricultural production in several respects. First, this research investigates agricultural production in Korean prior to 1980 based on county-level data, whereas most of previous studies that looked into the period are largely based on aggregate data of the country as a whole. Secondly, this study is the first to utilize the comprehensive county-level agricultural data on both outputs and inputs that are drawn from statistical yearbooks covering the two decades from 1960 to 1980. Finally, the present studies consider a wider range of agricultural inputs than those included in previous studies, including individual machinery and chemical fertilizer.

The area planted with all food crops and the size of rice-cultivating area increased and reached the peak in the mid 1965s. Afterwards, it declined over time. During the Korean War (1950 to 1953), the cultivated area temporarily diminished perhaps due to wartime destructions. The area of arable lands considerably differed by province. During the three decades under study, the province with the largest planted area was Gyeongbuk, followed by Jeonnam and Gyeongnam. By the 1970s, Jeonnam overtook Gyeongnam at the number one province in terms of the arable land area.

The farm population sharply fell from 1949 to 1951 as a consequence of wartime deaths. After the Korean War, the farm population gradually increased until 1967, and then declined over time thereafter. During the three decades under study, the top three provinces in terms of the size of farm population were Jeonnam, Gyeongbuk, and Gyeongnam. Even if the farm population is standardized according to age and gender compositions, these patterns of changes in labor input across times and provinces remain unchanged.

The number of major agricultural machines, such as power tillers, auto sprays, and tractors, increased sharply from the early 1970s. However, the trends should be cautiously interpreted because the relatively small number of machines in the early 1960s could result from the larger number of missing observations. Nevertheless, it seems evident that the availability of agricultural machines increased over time, although we cannot be sure how much under-reporting affects the real trend. If we compare years 1969 and 1980 when the number of counties with the number of machines reported remained unchanged, the number of power tillers increased more than 30 times. The increasing trend is similar to those of auto sprays and tractors. The patterns of changes in the use of agricultural machines substantially differed by region.

As in the case of agricultural machines, the use of chemical fertilizers dramatically increased from the early 1970s. Again, however, the trends should be taken cautiously because there were more counties in the 1960s where fertilizer consumption is unreported than in the 1970s. To address such potential problems, I also examined the yearly consumption divided by the number of counties (i.e., the average consumption per county). The results indicate that the rapid increasing trend largely captures the increase in the number of counties reporting fertilizer consumption. Furthermore, large fluctuations in each province’s fertilizer consumption are observed. These results suggest that samples with information on fertilizers should be selected so that variables for chemical fertilizers can be considered in the estimation of agricultural production functions.

Combining the county-level data on agricultural outputs and inputs, I estimated production functions of rice, the most important crop in Korean agriculture. The variable pertaining to land input is defined as the size the rice-cultivating area (measured in hectare) in each county in a given year. For labor input, I use the standardized population living in farm households cultivating rice. Since variables pertaining to capital inputs are not universally reported in provincial or county Annual Statistics, there is a tradeoff between considering more variables on inputs and additional loss of observations. I attempt to circumvent this problem in the following two ways. Firstly, I estimate agricultural production functions excluding the variable on capital inputs, and then extend the model by including additional capital inputs to examine the effects of the sample selections arising from missing observations of capital inputs. Secondly, I only focus only on major components of capital inputs to achieve a balance between omitted variables and missed observations. Finally, I included only the counties with information on a particular type of capital input (machine or fertilizer) to avoid bias arising from underreporting in early periods.

The results of regression analyses suggest that local rice production in Korea during the period from 1960 to 1979 was largely determined by land and labor inputs. Changes in these two factors explain more than 95% of variations in rice production across counties and years. It is difficult to estimate accurately the contributions of capital inputs to agricultural production because data are available only for selected capital inputs and for selected places and years. The results based on using three major agricultural machines of the time (power tillers, automatic sprays, and tractors) suggest that capital inputs also played significant roles in changing agricultural production, especially across times.

Given the currently available county-level data on agricultural inputs, it would be reasonable to use the number of major agricultural machines as an index of capital input in estimating agricultural production function. Land, labor, and agricultural machines explain over 98% of the variations in rice production across counties and years. Using the data and estimated regression coefficient for each input, it will be possible to estimate the agricultural total factor productivity as well as each factor productivity in each county and year. I remain it as future research agenda to investigate how natural, institutional and technological factors (such as natural disasters, local organizations, and new methods) affected these measures of local agricultural productivity.

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Appendix

Table A1| Converting Rules: Land Area

m^2	a	ha	*Danbo*	*Jeongbo*
1	0.01	0.0001	0.0010083	0.00010083
100	1	0.01	0.10083	0.010083
10000	100	1	10.083	1.0083
991.74	9.9174	0.099174	1	0.1
9917.4	99.174	0.99174	10	1

Note. Danbo(段步)=Dan(段)=Banbo(反步)=Ban(反), Jeongbo(町步)=Jeong(町)=Jeongban(町反).

Table A2| Converting Rules: Weight

Gwan(貫)	kg	t	*Geun*(斤)
1	3.75	0.00375	
0.26666	1	0.001	
266.666	1000	1	
	0.6	0.0006	1

Note. t=ton=M/T=屯=噸, kg=瓩

Table A3| Average Caloric Consumption at Given Ages as a Proportion of That of Males Aged 20 to 39 by Sex

Age interval	Average Caloric Consumption of Males at Given Ages as a Proportion of That of Males Aged 20 to 39	Average Caloric Consumption of Females at Given Ages as a Proportion of That of Males Aged 20 to 39
0 to 4	0.4413	0.4367
5 to 9	0.7100	0.6667
10 to 14	0.9000	0.8000
15 to 19	1.0167	0.7833
20 to 39	1.0000	0.7333
40 to 49	0.9500	0.6967
50 to 59	0.9000	0.6600
60 to 69	0.8000	0.5867
70 or more	0.7000	0.5133

Source: Fogel (1993: 9).

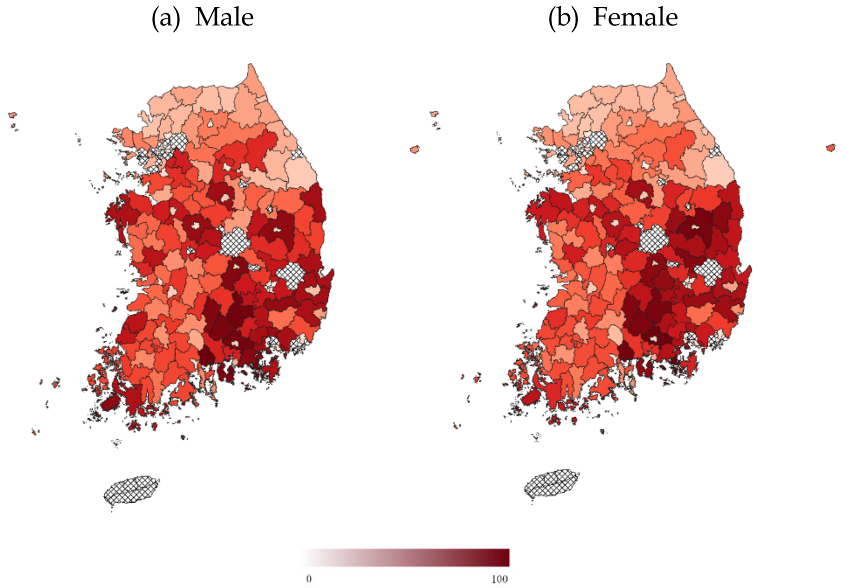
Table A4| Consumption of Chemical ertilizers by Raw Materials (tons)

Year	Nitrogen	Phosphoric acid	Potassium
1961	59,788	30,708	1,798
1962	135,081	40,232	4,879
1963	69,048	32,695	10,154
1964	45,218	35,878	9,786
1965	41,783	20,980	10,344
1966	95,045	79,144	41,672
1967	126,036	63,440	103,564
1968	88,475	40,790	24,335
1969	117,654	50,040	32,075
1970	133,595	45,737	29,999
1971	128,404	61,543	33,029
1972	141,999	67,278	36,538
1973	280,993	157,672	95,919
1974	286,241	146,430	95,785
1975	311,234	152,109	102,947
1976	249,988	92,203	89,329
1977	249,376	130,953	85,197
1978	294,662	141,361	107,425
1979	292,505	148,096	125,449
1980	301,347	139,458	125,467

Table A5| Number of Agricultural Machines

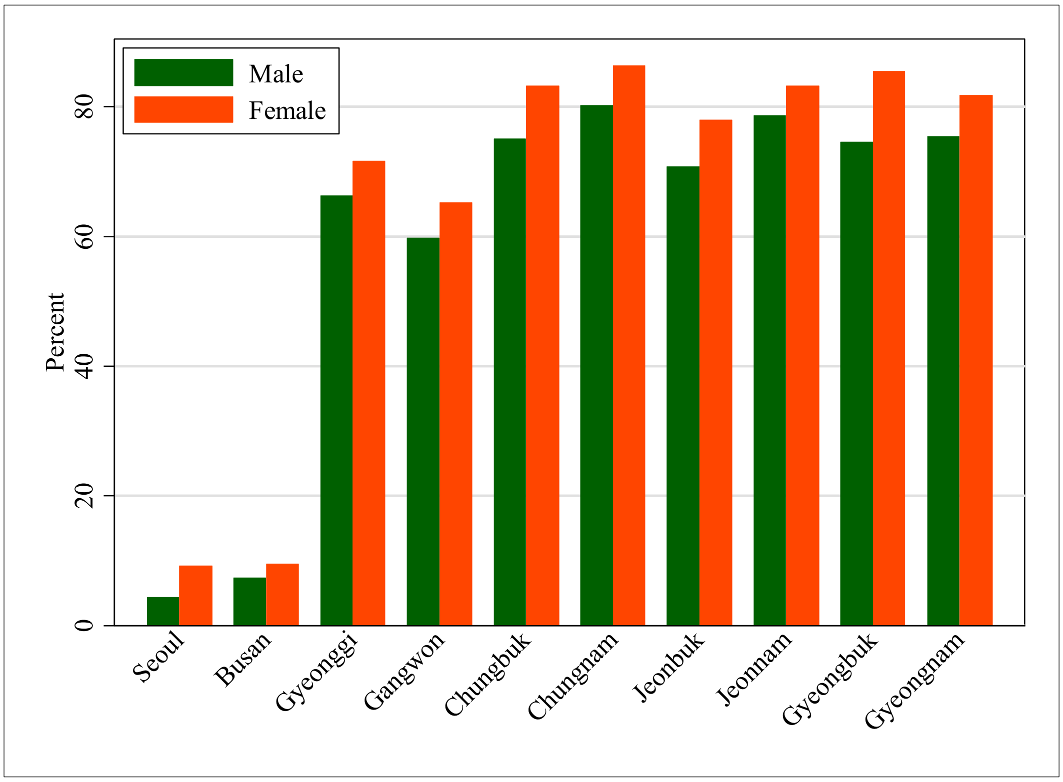
Year	Power tiller	Auto spray	Tractor
1960	0	30	0
1961	6	632	0
1962	71	62	0
1963	257	653	0
1964	491	797	0
1965	321	1,715	0
1966	1,063	3,943	0
1967	2,514	4,120	8
1968	4,902	2,193	7
1969	8,680	971	18
1970	11,601	3,031	4
1971	16,315	4,775	51
1972	24,689	2,378	73
1973	31,241	2,772	151
1974	49,316	3,935	254
1975	70,742	5,449	385
1976	100,366	7,227	529
1977	147,545	10,065	1,029
1978	187,096	13,731	1,460
1979	227,666	18,538	1,852
1980	279,502	23,064	2,441

Figure A1| 1962 Agricultural Population by Districts



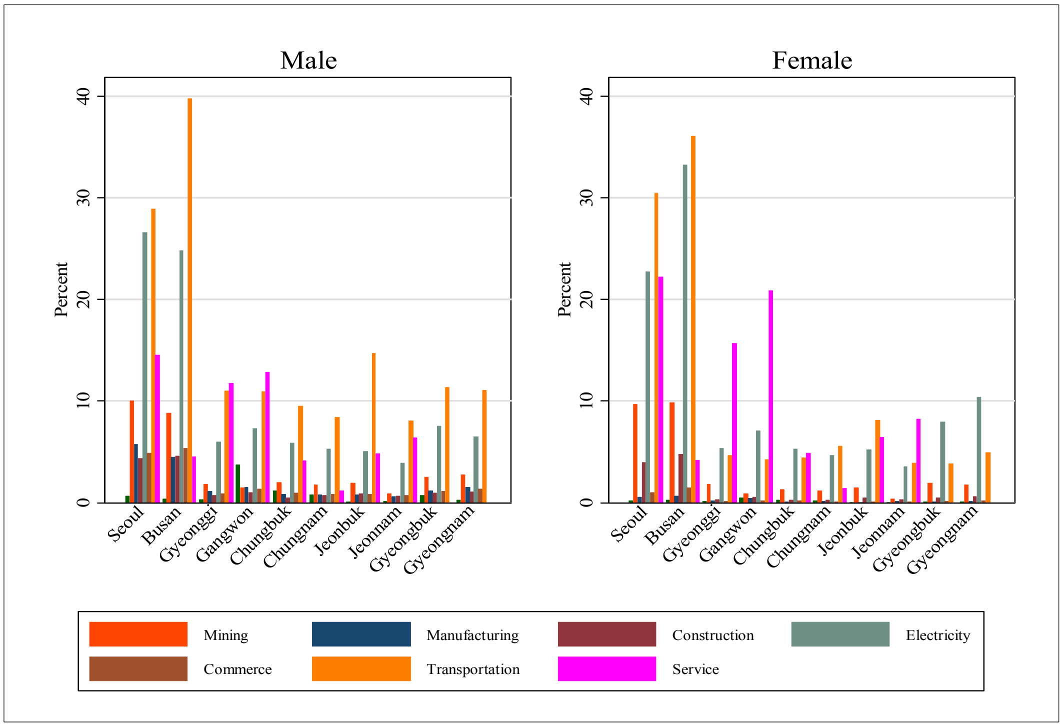
Notes: Each panel depicts the distribution of agricultural population ratio by districts. Since the representativeness of 1962 is the highest among the years of sample periods, the ratio is calculated by dividing the agricultural population by the total industrial population in 1962. The graph on the left is for the male population and the graph on the right is for female, respectively.

Figure A2| 1962 Agricultural Population by Provinces



Notes: This graph shows the distribution of agricultural population ratio by provinces. Since the representativeness of 1962 is the highest among the years of sample periods, the ratio is calculated by dividing the agricultural population by the total industrial population in 1962.

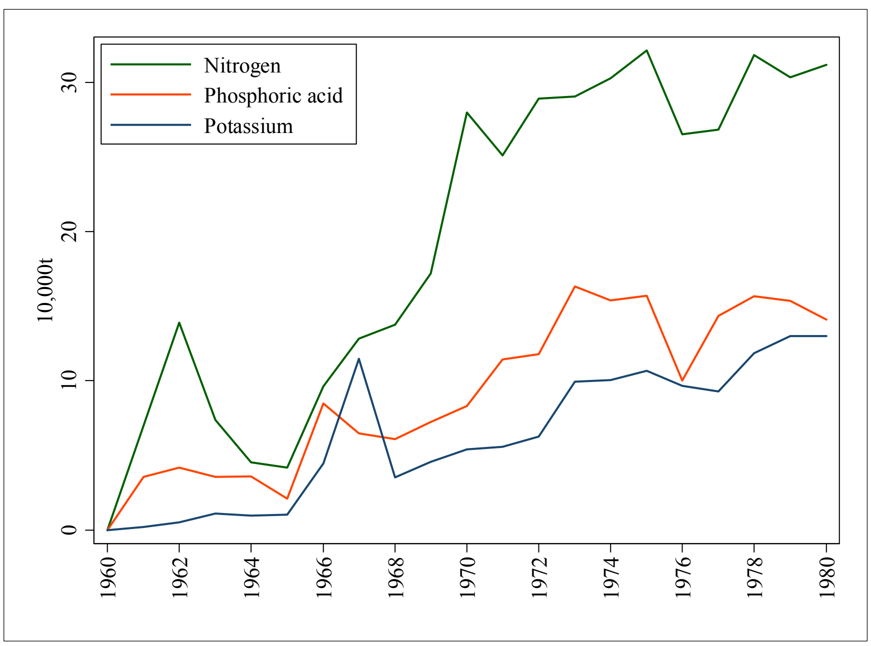
Figure A3| 1962 Population by Industries



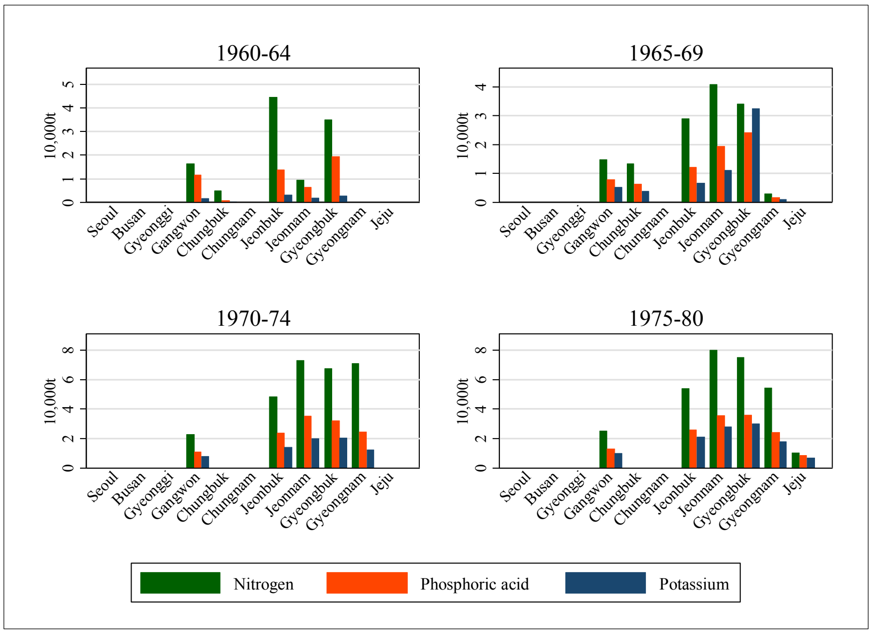
Notes: This graph shows the distribution of each industrial population ratio by provinces. Since the representativeness of 1962 is the highest among the years of sample periods, the ratio is calculated by dividing the each industrial population by the total industrial population in 1962.

Figure A4| Consumption of Chemical Fertilizers by Raw Materials

(a) Yearly National Trend



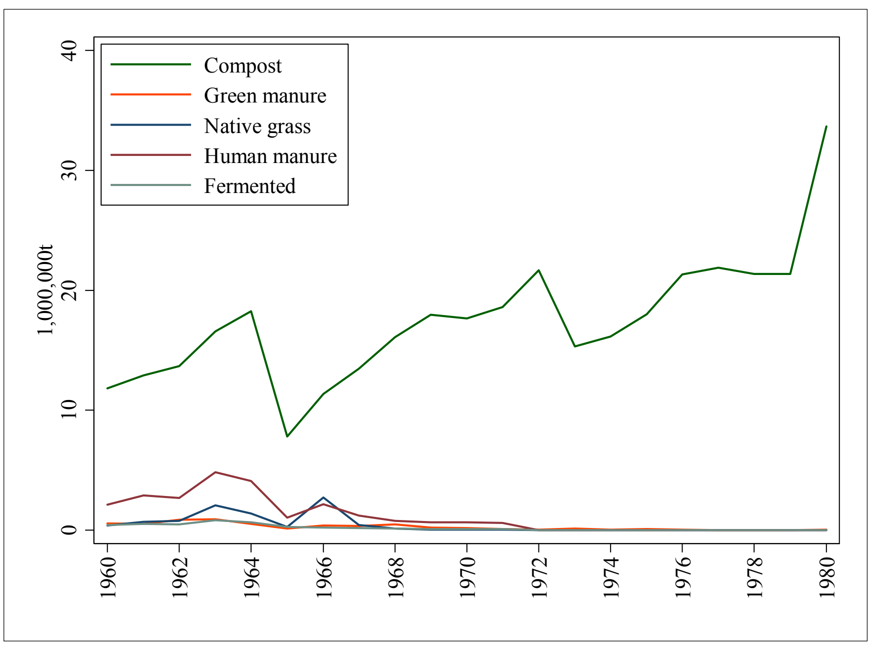
(b) Provincial By Five Years



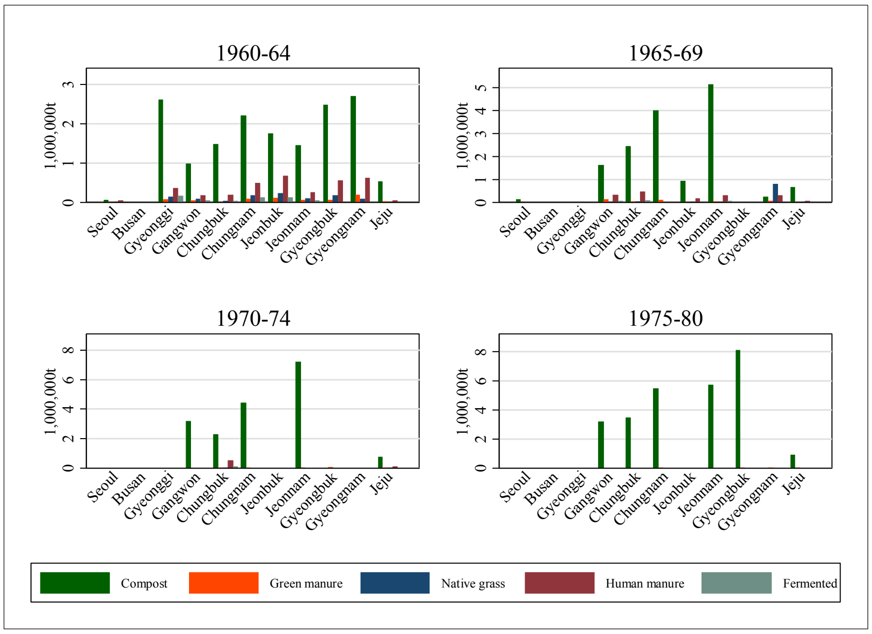
Notes: Each panel depicts the consumption trend of chemical fertilizers by raw materials. The upper panel shows the national trends, and the lower panel shows provincial variations over five years. The relatively little consumptions in the early 1960s and in Seoul, Busan, Gyeonggi, Chungbuk, Chungnam, Jeju are caused by lack of data.

Figure A5| Consumption of Fertilizers

(a) Yearly National Trend



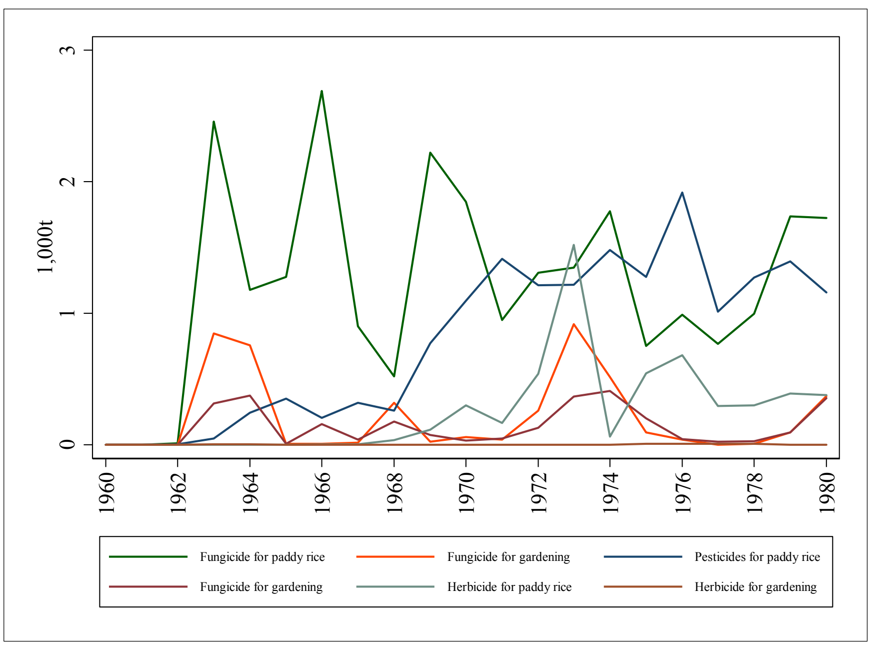
(b) Provincial By Five Years



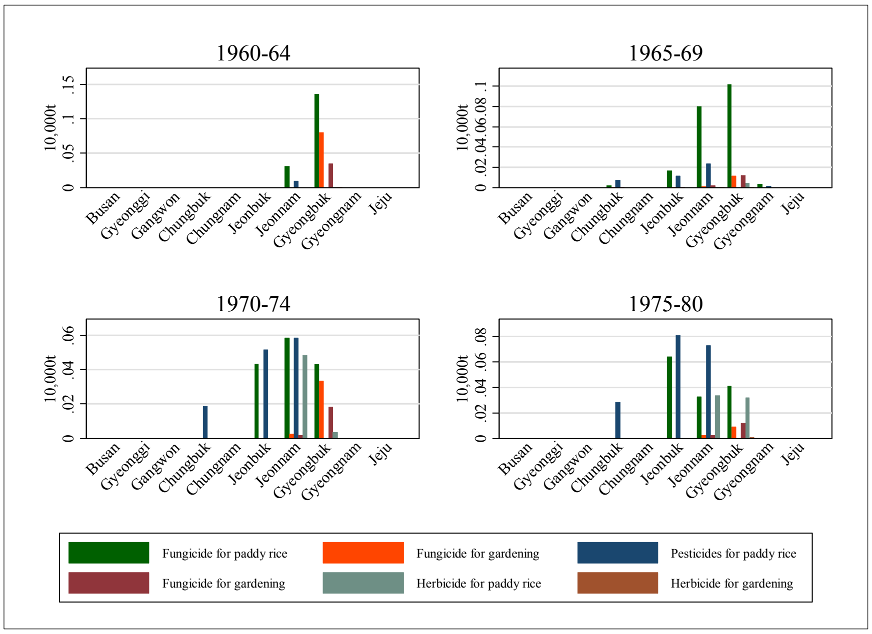
Notes: Each panel depicts the consumption trend of fertilizers. The upper panel shows the national trends, and the lower panel shows provincial variations over five years. The relatively little consumption in 1965 is caused by lack of data. The data of native grass, human manure, and fermented were not reported since 1972.

Figure A6| Consumption of Pesticides by Subject of Application

(a) Yearly National Trend

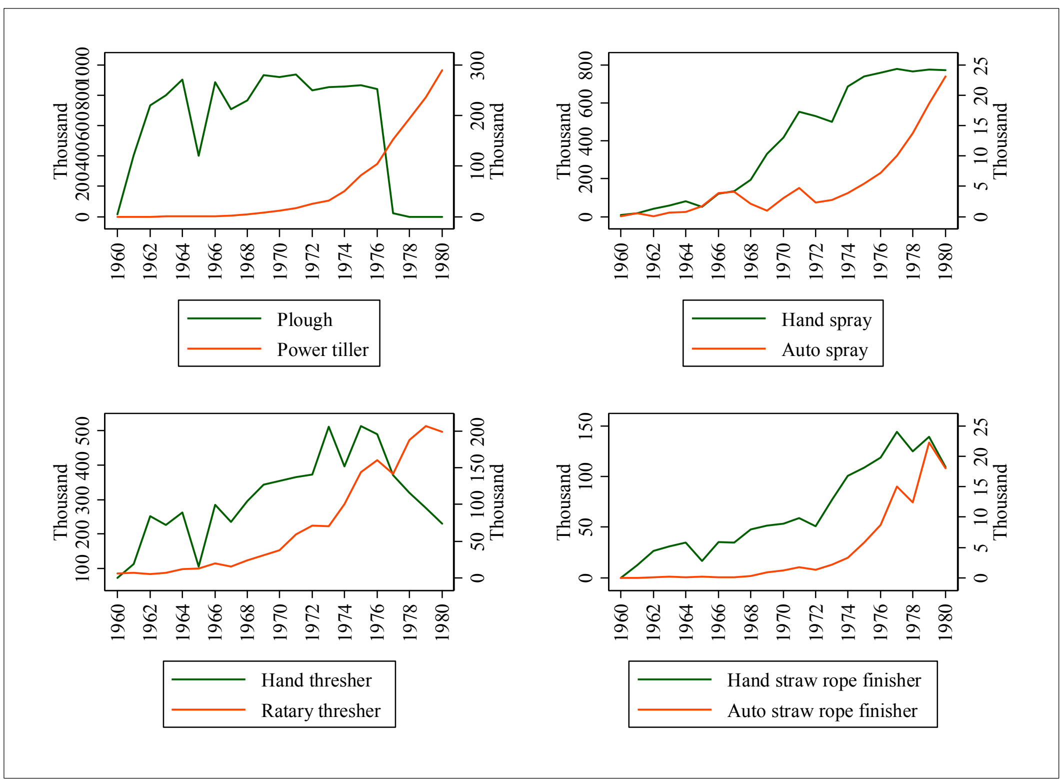


(b) Provincial By Five Years



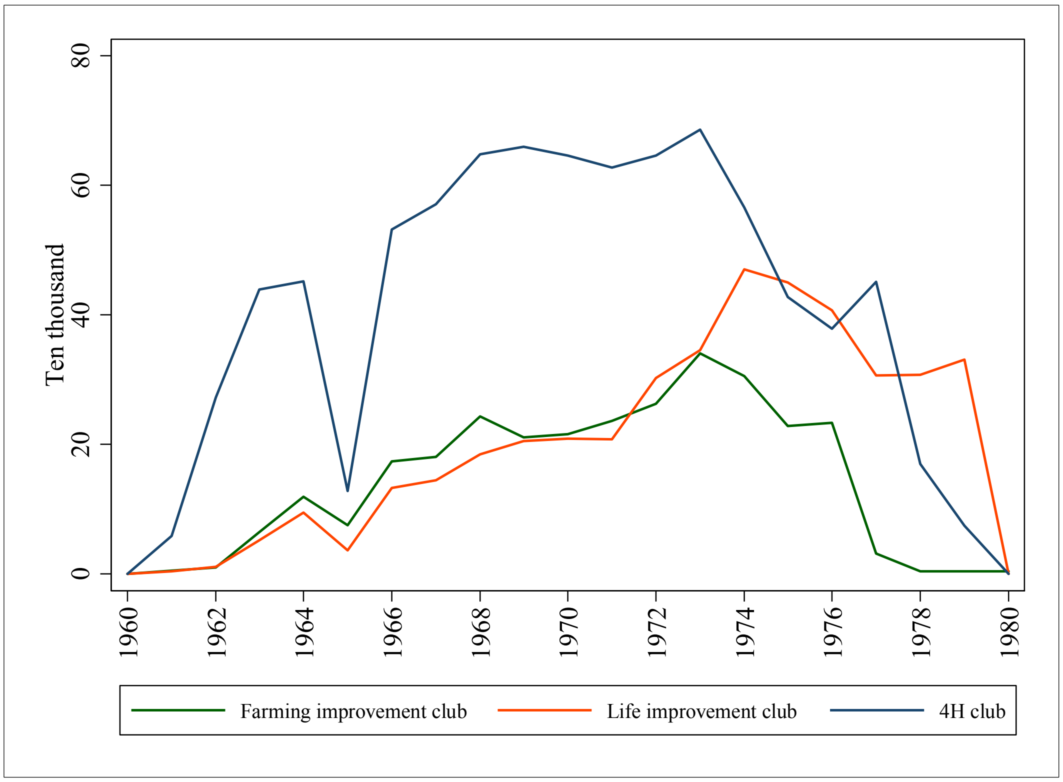
Notes: Each panel depicts the consumption trend of chemical fertilizers by the subject of applications. The upper panel shows the national trends, and the lower panel shows provincial variations over five years. The low level of consumption in the early 1960s is caused by lack of data. The data were recorded mainly in Jeonbuk, Jeonnam, and Gyeongbuk provinces.

Figure A7 | Yearly National Trend of Possession of Agricultural Equipment



Notes: Each panel shows the status of agricultural equipment holdings by year. The relatively small number of holdings in the early 1960s, 1965, and late 1970s are caused by lack of data.

Figure A8 | Number of Members of Agricultural Education Clubs



Notes: This graph shows the number of members of agricultural education clubs by year. The relatively small number of members in the early 1960s, 1965, and late 1970s are caused by lack of data.