Estimating Long-Term Economic Statistics of Japanese Agriculture: 1963-2011

by Koki Takayama and Daisuke Takahashi

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Abstract:

In this study, we estimate the long-term economic statistics of Japanese agriculture from 1963 to 2011 and then calculate the total factor productivity using the Törnqvist index. We show that total factor productivity increased continually throughout the estimation period. In the early period, from 1963 to the middle of the 1980s, productivity growth was driven by a shift from rice farming to vegetable, fruit, or livestock production along with a substitution of labor and land for capital and intermediate inputs. In the late period, from late 1980s to 2011, productivity growth was driven by the withdrawal of less productive farms, despite overall declining production.

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1. Introduction

According to past research, Japan's agricultural output has been supported by growth in total factor productivity (TFP). Yamada (1991) made a significant contribution to the estimation of *Long-Term Economic Statistics* (LTES) and analyzed agricultural productivity between 1880 and 1985. Yamada (1991) demonstrated that most of the agricultural output over that period resulted from TFP growth. Hayami and Godo (2002) extrapolated the estimates in Yamada (1991), confirming the continuation of the same trend through to 1995.

Improvement of agricultural productivity is still important in the present day. The demand for food is projected to increase globally due to growing populations and income per capita. In Japan, where the working-age population is shrinking and the trade of agricultural products has been increasingly liberalized, improving agricultural productivity is essential to ensure a stable supply of food in the future. Therefore, we need to understand changes in productivity and to analyze the causes behind such fluctuations. The main objective of this study is to show the long-term changes in macro-level TFP in the agricultural sector.

A prerequisite for the measurement of TFP is the estimation of data regarding agricultural outputs and inputs. Official statistics can be used to estimate outputs, including data from the *Economic Accounts for Agriculture and Food Related Industries* (henceforth "*Economic Accounts*") and *Statistics of Agricultural Income Produced*, which are both published by the Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF). However, neither the quantity of capital and labor input nor the factor share of each production factor can be obtained from official statistics. To estimate inputs as accurately as possible, past studies have developed aggregated macro-level statistics by combining different statistics. Umemura et al. (1966) and Yamada (1966) made significant contributions to LTES by aggregating long-term macro-level statistics between the 1870s and 1963 through the combination of various data. Even today, their contributions are valuable basic materials when considering long-term trends in the agricultural sector and the Japanese economy.

In a related study, Izumida (1987) develops macro-level statistics of post-war Japanese agriculture. Specifically, the study focused on aggregation methods for statistics of capital stock and developed measures for return on capital and return on investment in the agricultural sector. Izumida's (1987) estimation method was later used in Kuroda's (1995) analysis of technological progress.

This study aims to estimate accurate macro-level statistics, to the most recent year, by referencing the methods used by Izumida (1987) and making use of the official statistics to develop the data aggregation methods from the existing research. Since the data used by Yamada (1991) and Hayami and Godo (2002) extrapolates the LTES estimates in a simplified way, the estimates in this study will also verify the TFP trends up to the 1990s.

The index method is used to estimate TFP in this study. Yamada (1991) and Hayami and Godo (2002) employ the chained Laspeyres index in their studies. In contrast, this study adopts the Törnqvist index, which has more desirable properties than the Laspeyres index. Previous studies, such as Doi (1985), Kuroda (1989), and Rahmatullah and Kuroda (2005), have used the Törnqvist index, but these studies provide TFP estimations using average data for each farm-size class, which are different from our estimates on macro-level statistics.

Other studies on the productivity of the Japanese agriculture have analyzed the regional trends of TFP, employing methods other than the index method. For example, Kunimitsu (2014) and Kunimitsu et al. (2016) analyze regional rice farming TFP using the Törnqvist and Malmquist indexes. Yamamoto et al. (2007), Kondo et al. (2010), and Kondo et al. (2017) analyze regional rice farming TFP trends using the Malmquist index. Moreover, Kawagoe et al. (1986) and Kuroda (1995) analyze technological progress and productivity through estimates of production and cost functions.

Outside Japan, the U.S. Department of Agriculture's Economic Research Service (ERS) measures TFP by producing estimates for production, labor, capital, land, and intermediate input in the agricultural sector[1]. Estimates made by the ERS are at the state and national level, and they construct a refined productivity measurement framework by carrying out a broad range of quality controls. According to these estimates, U.S. agriculture has expanded production due to TFP growth, despite decreasing levels of input. The European Commission (EC) also measures agricultural TFP in each of its member states (European Commission, 2016). This research shows that TFP growth continues across the EU, though it is slowing, and there are differences in TFP growth between the member states.

Beyond the agricultural sector, there are ample studies which construct databases to measure national productivity by industry. The EU KLEMS project is an example of an international comparison of productivity. In Japan, the Research Institute of Economy, Trade and Industry (RIETI) manages the Japan Industrial Productivity (JIP)[2] database to measure productivity and the Keio Economic Observatory (KEO) has established the well-known KEO Database[3]. The JIP's measurement framework is based on an input-output table, and the methodology and data sources for the agricultural-sector macro statistics estimates differ significantly from the past research mentioned above. The JIP has come to be widely cited in discussions of Japanese agricultural productivity trends. For instance, Esteban-Pretel and Sawada (2014), based on the JIP, discuss structural change and economic growth in Japan using a two-sector model of

1) The data and estimation methods are published on the ERS website "Agriculture Productivity in the U.S." (https://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us/). Please see Ball et al. (2016) for a published article on this topic.

2) The JIP participates in the EU KLEMS project. Data and estimation methods are published on the RIETI website under "JIP Database" (https://www.rieti.go.jp/jp/database/jip.html). As of end of May 2020, the most recent version was the 2018 publication (JIP 2018). Estimation methods for the 2006 version (JIP, 2006) are summarized by Fukao and Miyagawa (2008).

3) For further explanation of the estimation methods, especially on capital, please see Nomura (2004).

agriculture/non-agriculture. The macro statistical measurement results produced in this study are also compared with the JIP estimates.

This study is organized as follows. Section 2 explains the estimation process for the macro statistics for Japanese agriculture. In particular, the methods developed from the existing researches are used to obtain the quantities and prices of labor and capital inputs. Section 3 provides an overview of the data estimation results explained in the previous section and compares them with previous research to discuss their noteworthy features. Section 4 explores TFP trends estimated from macro statistics and Section 5 concludes.

2. Estimates of Macro Statistics

This section discusses index-based TFP estimation methods, followed by an explanation of the estimation methods for labor, capital, and land inputs. We do not estimate for the input of intermediate inputs or for agricultural output. Instead, the study utilizes their real values which are converted from the nominal values taken from *Economic Accounts* using the price indexes drawn from the MAFF's *Statistics on Commodity Prices in Agriculture*.

1) Total Factor Productivity

This study estimates TFP using an index method[4]. When this method is adopted, the TFP growth rate is obtained as the difference between the growth rates of index Q (total quantity of agricultural production) and index X (total quantity of inputs).

$$\ln\frac{\mathrm{TFP}_t}{\mathrm{TFP}_{t-1}} = \ln\frac{Q_t}{Q_{t-1}} - \ln\frac{X_t}{X_{t-1}} \tag{1}$$

This study employs the Törnqvist index method to aggregate the total input index X and total output index Q. This index is a discrete-time data approximation of the Divisia index and

4) Please see Jorgenson and Griliches (1967) for details on the estimation theory.

the superlative index which is exact for the translog production function (Diewert, 1976)[5].

When the following conditions are satisfied, TFP using the Törnqvist index will exactly match the rate of technological progress included in the translog production function: 1. The producer follows the marginal principle; 2.The production technology is input-output separable; 3. The technological progress is Hicks-neutral; and 4. The production function is homogenous of degree one. However, Kawagoe et al. (1986) and Kuroda (1995) demonstrate the presence of biased technological progress, while Kuroda (1995) shows the existence of economies of scale. Therefore, while TFP can be interpreted as an index of productivity, it is not necessarily consistent with technological progress.

The aggregation method of the total output index Q is as follows. $q_{i,t}$ is the quantity of production good i in year t, $s_{i,t}$ is its value share in overall value of production, and $p_{i,t}$ is its price.

$$\ln\frac{Q_{i,t}}{Q_{i,t-1}} = \sum_i \frac{s_{i,t} + s_{i,t-1}}{2} \ln\frac{q_{i,t}}{q_{i,t-1}} \tag{2}$$

$$s_{i,t} = \frac{p_{i,t} q_{i,t}}{\sum_j p_{j,t} q_{j,t}}$$

In other words, the growth rate of the Törnqvist total output index Q can be obtained as a weighted average of growth rate of each output using its value share as a weight. . For the total input index X, it is assumed that inputs can be separated into the four production factors of labor, capital, land, and intermediate inputs. Then, a two-stage aggregation is carried out wherein the Törnqvist index is aggregated for each production factor, followed by the calculation of the total input index from each production factor index.

5) The index is defined to be exact for a production function when the ratio of the index values from two time points matches the ratio of the solutions to the maximum problem of the production function. The index is defined to be superlative when it is exact for a function which is a second order approximation of a homogenous function of degree one.

2) Aggregation Method for Labor Input

(1) Quantity of Labor Input

Quantity of labor input is defined as hours worked within a certain period of time. Average hours worked per household for every year are available in the MAFF's *Survey of the Farm Household Economy*. The simple method to estimate hours worked using this statistic is to multiply the national average for hours worked per household by the total number of domestic farming households. This is referred to as the simple aggregation method in Izumida (1987).

However, the simple aggregation method can lead to potential bias: it is directly affected by the upper-size bias found within the *Survey of the Farm Household Economy*. It also suffers from the fact that farm entities, beyond the survey population in the *Survey of the Farm Household Economy* and *Census of Agriculture and Forestry*, are not included in the estimation results.

The upper-size bias means that the farming household sample in the *Survey of the Farm Household Economy* has a smaller proportion of small-scale farmers than is actually the case, and this higher proportion of large-scale farmers means that the average values per farming household are biased toward large-scale farmers. The sample allocation in the *Survey of the Farm Household Economy* is carried out based on the recent census. However, the allocation does not reflect the actual number, because it intends to avoid setting the surveyed number in each farm size category to 0 for areas where there are few farm households.

To counteract these issues, Izumida (1987) aggregates the hours worked with the following procedure. First, a farm household's hours worked is obtained by multiplying the average values for each farm size by the corresponding number of farms of that size. Then, the ratio of farm entities not surveyed in the *Survey of the Farm Household Economy* to the surveyed farm households, k, is obtained. Finally, the hours worked for the agricultural sector is obtained by multiplying the hours worked of surveyed farm households by $(1+k)$. This method is referred to as the stratified aggregation method in Izumida (1987).

The ratio k can be obtained by comparing the total production value for agriculture, and the aggregated production value of the farm household in the *Survey of the Farm Household Economy*. This method is used by Zhang and Izumida (1997) to calculate the ratio k. When the ratio k is calculated from production values, the labor productivity of farm households and other types of farm entities is assumed to be equivalent.

The production value of farm households can be estimated by aggregating gross agricultural income per surveyed farm household from the *Survey of the Farm Household Economy* and using the stratified aggregation method. Meanwhile, for the total agricultural production value, the total output data from *Statistics of Agricultural Income Produced* is used. Finally, it should be noted that the gross agricultural income in the *Survey of the Farm Household Economy* includes miscellaneous agricultural income such as rent from leasing agricultural machinery, but such activities are not included in the total output in *Statistics of Agricultural Income Produced*. Therefore, we deduct miscellaneous agricultural income from gross agricultural income when estimating a farm household's production value.

There is another possible bias among regions in the *Survey of the Farm Household Economy* for reasons similar to the upper-size bias; namely, the sample allocation among regions does not necessarily reflect the actual distribution. Because this regional bias cannot be counteracted using the stratified aggregation method, this study has further developed the method with reference to Yamada (1991) and aggregated hours worked of farm households from the average values by agricultural region and by farm size. We refer to this method as the two-stage stratified aggregation method.

The specific procedure of the two-stage stratified aggregation method is as follows. First, ratio k is calculated, as shown in Equation (3) below. The subscript p represents the region, and i indicates the farm size category. Y represents the total output value, obtained from the

Statistics of Agricultural Income Produced; $N_{p,i}$ shows the number of farm households in the *Census of Agricultural and Forestry* and the *Survey on Movement of Agricultural Structure*; and $y_{p,i}$ indicates the average value of a farm household's gross agricultural income less the miscellaneous agricultural income in the *Survey of the Farm Household Economy*.

$$1 + k = \frac{Y}{\sum_p \sum_i N_{p,i} y_{p,i}} \tag{3}$$

In the next stage, hours worked for all agricultural laborers, separated by sex, L_g, is calculated as shown below in Equation (4). Note that $l_{g,p,i}$ represents the average hours worked of an agricultural worker of sex g per household from region p and farm size i in the *Survey of the Farm Household Economy*.

$$L_g = (1 + k) \sum_p \sum_i N_{p,i} l_{g,p,i} \tag{4}$$

Finally, the Törnqvist index for labor input is aggregated from the hours worked by sex.

(2) Wages

Hourly wages for agriculture are calculated with reference to Izumida (1987). Up until 1994, the average number of labor hours per day was calculated by dividing the number of family labor hours for a year recorded in the *Survey of the Farm Household Economy* by the number of family working days. Then, the hourly wage was determined by dividing the daily wage rate for temporarily hired labor from the MAFF's *Statistics on Commodity Prices in Agriculture* by the average number of labor hours per day. Since 1995, the number of working days becomes unavailable in the *Survey*. However, since the average number of labor hours per day between the mid-1980s and 1994 are stable, this study uses the average value for the period of 1991-1994 to estimate this figure for subsequent years. Moreover, because the publication of the wage rate for temporarily hired labor in the *Statistics on Commodity Prices in Agriculture* ceased in 2008, we extrapolated the agriculture wage rate for temporarily hired labor (per day general agricultural work, by sex) found in the National Chamber of Agriculture's *Survey on Farm Work Prices and Farm Wage Rate*.

3) Aggregation Method for Capital Input

(1) Estimation Framework

Regarding capital input, because neither the user cost of capital (rental price) nor the quantity of service generated by capital usage is published, we estimate these statistics by making several assumptions.

The quantity of capital service is assumed to be proportional to the quantity of capital stock. Equation (5) is obtained based on the capital service of asset i in year t, denoted as $K_{i,t}$, and the capital stock at the end of year $t-1$, denoted as $S_{i,t-1}$, where φ_i is a coefficient that converts capital stock into capital service:

$$K_{i,t} = \varphi_i S_{i,t-1} \tag{5}$$

Since the capital service growth rate $\ln K_{i,t}/K_{i,t-1}$, required for Törnqvist index aggregation, is equal to the capital stock growth rate $\ln S_{i,t-1}/S_{i,t-2}$, we also need to consider methods for obtaining the capital stock growth rate.

When capital is put to production activity as a new product, the decrease in efficiency and the occasional retirement of capital means that the expected productive capacity will gradually decrease over time. Hence, for the TFP measurement, the capital stock $S_{i,t}$ in Equation (5) needs to reflect the decline in productive capacity[6].

Capital stock estimation methods include the physical stock value method (PS method), the perpetual inventory method (PI method), and the benchmark year method (BY method). The PI method aggregates past capital formation to estimate capital stock, as shown in Equation (6).

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6) The capital stock here is productive capital stock, as defined by the OECD (2009) and Nomura (2004). This definition differs from the gross capital stock and net capital stock definitions in Egaitsu (1985).

In this equation, $S_{i,t}$ is the capital stock of asset i at the end of year t, and $I_{i,t}$ is capital formation in year t. Moreover, $d_{i,\tau}$ is a coefficient representing the relative productive capacity of the asset of equipment age τ, based on the time of the new product, and it approaches 0 as equipment age τ increases.

$$S_{i,t} = \sum_{\tau=0}^{\infty} d_{i,\tau} I_{i,t-\tau} \tag{6}$$

$$1 = d_{i,0} \geq d_{i,1} \geq d_{i,2} \geq \cdots \geq 0$$

$d_{i,\tau}$ is the product of the age-efficiency profile (a process in which efficiency declines as equipment age increases, under the premise that the equipment is not retired) and survival distribution by equipment age; the OECD (2009) calls $d_{i,\tau}$ the age-efficiency/retirement profile.

The BY method determines capital stock from capital stock at the base time, as well as capital formation and depreciation at following time points. Deriving from $d_{i,\tau}$, consider $m_{i,\tau} = -(d_{i,\tau} - d_{i,\tau-1})$, which represents the reduction in productive capacity within a certain year and is also referred to as the depletion rate. By using m, the relationship between S and I in Equation (6) can be expressed as follows:

$$S_{i,t} = S_{i,t-1} + I_{i,t} - \sum_{\tau=1}^{\infty} m_{i,\tau} I_{t-\tau} \tag{7}$$

The second term on the right-hand side represents capital formation in the present term, while the third term shows the natural decrease in capital stock in the previous term-end, with the difference being the change in capital stock.

Regardless of the method used, capital stock estimates require assumptions about the form of $d_{i,\tau}$. Potential models for age-efficiency profiles include the geometric age-efficiency profile, where depreciation occurs at a constant rate in comparison to the previous year

$((1-\delta_i)^{\tau}$, where δ_i is the depreciation rate and $0<\delta_i<1$). Other models include the linear profile, where decline occurs based on a constant range (if service life is L_i, then the range is defined by $1-\tau/L_i$ when $\tau \leq L_i$, and 0 when $\tau > L_i$), and the one-hoss shayprofile, where the efficiency of a new product is maintained until the service life ends (i.e. it is 1 when $\tau \leq L_i$ and 0 when $\tau > L_i$). In many studies, including the JIP and Nomura (2004), the geometric profile is adopted for the age-efficiency/retirement profile because it facilitates simple estimate handling. By contrast, the ERS employs the rectangular hyperbola profile to define the age-efficiency profile: $\frac{L_i-\tau}{L_i-\beta_i\tau}$, when $\tau \leq L_i$, and 0 when $\tau > L_i$ (β_i is the parameter determining curvature and $\beta_i < 1$). Both the PI and BY methods require setting the parameters of depreciation rate, δ_i, as well as those for service life, L_i and β_i, to some fixed value. However, because the depreciation rate and service life can change depending on the time of manufacture, this can give rise to estimation bias.

The PS method directly registers the capital stock owned by the producer at each point in time. The PS method does not require a retirement probability distribution because the capital stock owned by the producer is directly observed. The PS method should have little bias in this respect. A drawback of this method is the difficulty of collecting data. However, regarding agricultural machinery, the number of machines owned by agricultural management entities is recorded in the *Census of Agriculture and Forestry*. As well, quantities can be found for a considerable number of other relevant items in this report. Consequently, this study estimates capital stock based on the PS method.

The one-hoss shay model was selected as the age-efficiency profile. This selection was made because the geometric profile assumes that the younger the capital, the more severe the decline in productive capacity, but this assumption is not actually the case, as discussed by Egaitsu (1986). In addition, the rectangular hyperbola profile assumes a convex upward function and is often close to the one-hoss shay model, such as in the estimation by the ERS in which $\beta_i = 0.75$ (buildings) and $\beta_i = 0.5$ (non-buildings, such as machineries). Finally, the PI method is used for some agricultural machinery when data cannot be acquired, but service life is estimated annually to mitigate any bias from fixing the parameters[7].

For capital user costs, Kuroda (1995) uses the capital service price model with original revisions. The capital service price model assumes the geometric profile for the age-efficiency/retirement profile and is expressed as the following equation (Jorgenson and Griliches, 1967; OECD, 2009).

$$c_{i,t} = p_{i,t}\left(r_t + \delta_i - j_{i,t}\right) \tag{8}$$

$c_{i.t}$ is capital service price (user cost), $p_{i.t}$ is capital replacement cost, $r_{i.t}$ is return on capital, δ_i is depletion rate, and $j_{i,t}$ is expected inflation rate. $c_{i.t}$ represents the price per capital service generated by one unit of capital stock.

Because this study employs the one-hoss shay model, it is not possible to use the capital service price model as discussed above. The ERS generalizes the capital service price model so it can be applied to all distributions, and this is applied to the one-hoss shay model. Specifically, the capital service price $c_{i.t}$ is determined using the following equation, where $T_{i,t-1}$ is the service life.

$$c_{i,t} = \frac{r^*_{i,t-1} p_{i,t-1}}{1 - \left(1 + r^*_{i,t-1}\right)^{-T_{i,t-1}}} \tag{9}$$

$r^*_{i,t-1}$ is the real return on capital, representing the opportunity cost of capital. The average contracted interest rates on loans and discounts published by the Bank of Japan are used as the nominal rate of return, converted to the real rate by the expected inflation rate for each asset.

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7) In Takayama (2009), adjustments are made for the technological progress embodied in capital values for tractors and cultivators. We do not apply this adjustment in this study, since this is difficult to apply to all items in the capital stock.

The expected inflation rate is calculated by the autoregressive AR (1) model from price data for each asset.

(2) Data

This study considers agricultural machinery, agricultural buildings, orchards, and livestock as capital.

The PS method is applied to agricultural machinery, and the data is taken from the *Census of Agriculture and Forestry*, which regularly publishes the number of machines (henceforth "main machinery") owned by farm entities including farm households. There are six kinds of main machinery: tractors and cultivators of less than 30PS, tractors of 30PS or more, pest control equipment (including power sprayers and power dusters), combine harvesters (including auto-detachable and normal types), rice transplanters, and rice and wheat dryers. For other agricultural machinery, capital formation is obtained from shipment volumes and values in the Ministry of Economy, Trade and Industry's *Yearbook of Machinery Statistics* and from import/export machine volumes and values taken from the Ministry of Finance's *Japan Trade Monthly Table*. Then, physical quantities are calculated using the PI method. The service life at each point in time is estimated based on the number of main machineries owned and the number of capital formation of machineries, with reference to Izumida (1987). Further, values of capital formation can be estimated using Izumida's (1987) procedure whereby capital formation is based on factory shipment prices. These values are converted to capital formation values in terms of a farmgate price base using a freight/margin ratio calculated from the Ministry of Economy, Trade and Industry's *Input Output Table*. Finally, the prices of agricultural machinery are obtained by dividing the values of capital formation by the physical quantities of capital formation.

This study considers greenhouses (glass and vinyl) and cattle sheds as agricultural buildings. Greenhouse areas are taken from the MAFF's *Survey on Glass and Vinyl House Installation for*

Horticulture. Cattle sheds are estimated from the *Survey of the Farm Household Economy* using the two-stage stratified aggregation method. For periods when the area of cattle sheds is not published in the *Survey of the Farm Household Economy*, the ratio between cattle shed area and livestock industry output values is used to extrapolate from existing data. In terms of prices of agricultural buildings, appraisal values per unit area are taken from the MAFF's *Evaluation Standard for Agricultural Fixed Assets*.

We do not estimate capital stock of barns and warehouses, which are included in Izumida (1987) and Yamada (1991). If barns and warehouses were to be included, we would need to rely on the *Survey of the Farm Household Economy.* Unfortunately, the publication period for these items only goes up to 1977. Further, estimating the exact contribution of barns and warehouses to agricultural production is problematic. According to the *Survey of the Farm Household Economy*, barns and warehouses account for 70% of the value of a farm household's assets of agricultural buildings. However, we think that excluding barns and warehouses should still result in reliable estimates.

For physical quantities of orchards, areas for mature and immature orchards are taken from the MAFF's *Statistics on Cultivated Land and Planted Area*. It is assumed that half the immature area can accounted for as mature conversion area to generate an aggregate measure of mature area. The cultivation prices per unit mature area from the *Evaluation Standard for Agricultural Fixed Assets* is used as the price of orchards.

For physical quantities of livestock, dairy cattle are considered, and working cattle are excluded. For physical quantities of dairy cattle, the numbers of mature and immature cows are taken from the MAFF's *Livestock Statistics*. Again, half the number of immature cows is set as the conversion number to mature cows. For prices, the study uses the farm household's average purchase price of a mature dairy cow, as recorded in the *Statistics on Commodity Prices in Agriculture*.

4) Aggregation Method for Land Input

For land input, the study measures cultivated land area by type and by prefecture, namely area of paddy fields, regular fields, orchards, and pastures. Since both cultivated land area and farm rent data can be used by prefecture, the growth rate of cultivated land area by area type and by prefecture is aggregated based on the Törnqvist index and used as the land input.

The aggregation method used for land input is based on cultivated land area, following Izumida (1987). Cultivated land area, rather than planted area, are used for land input because the land rent represents the compensation value for renting land for one year. This study differs from Izumida (1987) in that cultivated land area statistics by type are used. As in Izumida (1987), paddy fields where crops other than rice are planted due to acreage control are deducted from the total paddy field area. This is because the crops under acreage control, produced mainly for eligibility of receiving subsidies, are regarded as not producing any added value[8)].

The data sources on cultivated land area by type are the MAFF's *Statistics on Farmland* for the years 1961 to 1964 and the *Statistics on Cultivated Land and Planted Area* for 1965 and later. The source for the acreage control area is the MAFF's *The Current Situation and Future Direction of Set-aside Program* for the years 1970 to 1977, and the MAFF's *Survey on Results of the Reorganization of Paddy Field Utilization Program* (names differ depending on the acreage control policy in each period) for 1978 to 2003. Since the area of land under the acreage control policy cannot be obtained for 2004 onwards, the area where only crops other than rice are planted is taken from the MAFF's *Area Survey* and used to extrapolate.

Statistics concerning land rent are obtained from the Japan Real Estate Institute's *Survey on Agricultural Land Price and Farm Rent*. Land rent data is taken from the *Survey on Agricultural*

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8) The price of crops under the acreage control program, such as wheat and beans, are much below the production cost. Farmers receive subsidies for participating in the acreage control program. Please see Takahashi (2012) for the details of rice policies.

Land Price and Farm Rent (henceforth "*Farm Rent Survey*"), which is superior to the National Chamber of Agriculture's *Survey on Farm Rent of Paddy Fields* and *Survey of Farm Rent of Upper Fields* in that annual data can be obtained for both paddy fields and upper fields. However, land rent data obtained from the *Farm Rent Survey* do not cover land rent for each cultivated land area by type. Meanwhile, the *Upper Field Rent Survey* records land rents for different crop fields. Therefore, the area of pasture is converted into regular field areas by multiplying the ratio of land rent of pasture against regular field data from the *Upper Field Rent Survey*. A five-year average is taken for the period of 1998 to 2002 for the land rent ratio by cultivated land type from the *Upper Field Rent Survey*. The conversion ratio is 0.611 pasture to one regular field, and this ratio is largely stable for the period published in the *Upper Field Rent Survey*. To avoid double counting crop capital, the conversion ratio of orchards is set at one.

Yamada (1991) includes area subject to the acreage control policy area in land input and sets land rent as 8% of the price of land, which is different from this study and Izumida (1987). This estimation can cause bias because land prices, affected by the non-farmland price, tend to deviate significantly from land rent trends.

3. Estimation Results and Verification

In this section, the estimation results for the statistics concerning labor and capital obtained using the above estimation method are compared with Yamada (1991), Izumida (1987), and the JIP[9)]. This study uses the same data source for cultivated land area and land rent as Izumida (1987). Further, the JIP does not include land in its production factors. Therefore, we do not compare the estimation results for land. We also do not compare the data of output and intermediate inputs because we use the data in the *Economic Accounts*. Instead, we compare

9) During the comparison, we do not consider the difference caused by defining a year as a calendar year (as per Izumida (1987) and this study) versus the fiscal year (as per Yamada (1991) and the JIP database).

the nominal input and output values to verify the consistency of the estimated values. Finally, trends in the factor inputs are discussed.

1) Estimation Results for Inputs

(1) Labor

Figure 1 shows trends in the totals for hours worked for agriculture bysex. This is shown for the sake of comparison because the labor input used for TFP estimations in this study is a Törnqvist index aggregated for hours of labor input bysex.

[Figure 1]

The hours estimated in this study are similar to Izumida (1987) and Yamada (1991), which both use almost the same method. The estimated values in Izumida (1987) are slightly larger than those in Yamada (1991) and this study. This is because the aggregation is not carried out by region. Moreover, the estimates in Yamada (1991) are slightly smaller than this study for 1980 onwards because this study has adjusted using the ratio for agricultural management entities other than surveyed farm households. Estimates for hours worked in JIP 2015 and JIP 2018 are both larger than in this study, although the extent of the difference gradually narrows.

Figure 2 is a comparison of nominal labor input value, which is the simple sum of the product of wages and hours worked bysex. Yamada (1991) does not show wages and labor input values.

[Figure 2]

The estimated values in this study increase from 1963 to 1985 and decrease from then onwards. This trend is largely consistent between this study and Izumida (1987) up until 1979. The estimation by Izumida (1987) is slightly higher than that of this study, reflecting the different quantity of labor input hours. A significant divergence can be seen in estimated values from 1981 onwards when this study is compared to JIP 2015 and 2018. Since labor input hours drop both in this study and in JIP 2015/2018, this difference is attributed to the rising wages accounted for in JIP.

(2) Capital

For capital, real capital stock appraised by fixed prices is compared. This is also shown for the purposes of comparison with previous studies because this study uses a Törnqvist index aggregated from physical quantity units by asset for capital input. The left-hand side of Figure 3 shows a comparison of the estimated values in this study, Yamada (1991), and Izumida (1987) for real capital stock at prices at 1975. The estimated values in Izumida (1987) and Yamada (1991) are larger than those in this study. This is primarily because this study does not include warehouses and barns within the scope of agricultural buildings. The three studies all show a trend of a rapid rise between 1963 and 1985.

[Figure 3]

The right-hand side of Figure 3 shows JIP 2018 and this study's estimates of real capital stock at prices at 2000. JIP 2015 differs significantly from JIP 2018 and this study because it includes public works investment such as land improvement projects. This study is therefore excluded from this comparison.

JIP 2018's capital stock decreases sharply in comparison to this study from 1994 onwards. Looking at the breakdown, the "other machinery & equipment," which includes agricultural machinery in JIP 2018, falls rapidly from 1994 to constitute less than one-third of the total in 2015. While the JIP uses the BY method with a fixed rate of depreciation, this study is based on the number of agricultural machines owned by agricultural management entities and the number of machines owned decreases more gradually than the rate of capital formation. This indicates that actual service life is increasing (i.e., the average depreciation rate is dropping), and the farm management entities are continuing to use old agricultural machinery as they hold back from new investment. This observation explains the difference between this study and JIP 2018. This study's average estimated service life value for all agricultural machinery is 5.0 years in 1963, rising to 7.4 years in 1970, 9.8 years in 1980, 14.1 years in 1990, 16.5 years in

2000, and 19.6 years in 2010.

Figure 4 shows a comparison of the nominal capital input values. Totals for JIP 2018 and this study are calculated by multiplying per commodity capital stock by capital service price, while Yamada (1991) is determined by multiplying the capital stock value by 8%.

[Figure 4]

As with capital stock, the estimated values of capital input in Yamada (1991) are slightly higher than in this study. The values in JIP 2018 are considerably higher than those in this study and they also decrease sharply. It is thought that one of the reasons for the sharp decrease in JIP 2018 is the decrease in capital stock.

(3) Comparison of the Input and Output Values

Figure 5 is a comparison of the totals for nominal input values and nominal output values for labor, capital, land, and intermediate inputs. It shows that the levels and trends of nominal input and output are consistent; in particular, the difference from 1970 onwards is within ±10%. The input values for production factors other than intermediate inputs are estimated from various forms of statistical data using the methods described above. The consistency between the output and input values indicates the validity of our estimation.

[Figure 5]

2) Summary of Estimation Results

Figure 6 shows the changes in factor input index and factor share of each input.

[Figure 6]

The total input index is almost the same between 1963 and the mid-1980s and then declines. The input with the largest increase in quantity from 1963 is capital, though it begins a downward trend from around 1990. Intermediate inputs also show an increase early in the study period, followed by a decline starting around 1990. Labor and land consistently fall in terms of input quantities. Labor, in particular, saw a significant decrease, with the input quantity in 2011 being one-fifth of that in 1963.

Regarding factor share, the share of labor accounts for more than 50% in 1963 and then drops significantly up until 2011. Intermediate inputs take up an increasing proportion of factor share, accounting for 35% in 1963 before rising to above 50% in 2011. The share of capital also increases until 1990.

4. Estimation Results of TFP

1) TFP Growth Rate Estimates

Figure 8 shows the total input index, total output index, and TFP estimation results. It shows growth in the total output index from 1963 until the latter half of the 1980s, followed by a downward trend. The total input index initially demonstrates a flat trend, but begins to fall around 1980, which is slightly before the total output index begins to decline. Although there are specific periods when TFP is stagnant or falling, it largely demonstrates an upward trend.

[Figure 7]

Table 1 provides a summary of growth accounting for total output, while Table 2 provides a breakdown of the total output growth rate.

[Table 1]

[Table 2]

The total output grew by 0.3% per year on average over the entire period. Total input contributed a yearly growth of -0.87%, and TFP growth contributed 1.17% of yearly growth, meaning that it was TFP growth that supported the total output growth. Looking at the breakdown for each production factor, intermediate inputs made the largest contribution at 0.49%. The contribution of capital is far from large in comparison to intermediate inputs at 0.08%, but capital still constitutes more than one-quarter of the total output growth rate. The contribution of land is negative at -0.06%, while labor input made a significantly negative contribution of -1.38%.

We investigate the trend of output and input by splitting the entire estimation period into the subperiod up to 1985, in which total output expanded, and the subsequent subperiod.

In the former subperiod, total input remained almost flat and TFP growth supported the rise in total output. In terms of changes in the inputs, capital and intermediate inputs increased, making up for the reduction in labor. This process of TFP growth based on factor substitution is consistent with the discussion on biased technological progress, as asserted by Hayami and Ruttan (1985). In terms of changes in the output, rice production declined due to the impact of policies related to acreage control, while fruits, vegetables, and livestock products increased significantly. Further, Kuroda (2017) demonstrates that changes in product composition can also encourage technological progress. From the above, it can be interpreted that TFP growth in the former subperiod was accompanied by technological progress.

The latter subperiod from 1985 onwards indicates a process different from the rise in TFP in the former subperiod. In this subperiod, the decline in labor continues and is accompanied by a decline in capital and intermediate inputs as well, resulting in a rapid decline in total input. Total output also declined, even though TFP growth compensated for the decline in total input to some degree. Looking at output, the downward trend of rice production continued and was joined by a decline in vegetables, fruits, and livestock products, all of which supported the total output in the former subperiod. It is thought that TFP growth in the latter subperiod is the result of producers' withdrawal with relatively lower productivity, such as smaller management entities, while management entities with high productivity remained and expanded production.

2) Comparison with Existing Research

We compare the estimated values for the TFP growth rate in this study with the analyses in Yamada (1991), JIP 2015, and JIP 2018. The estimated values are shown in Table 3.

[Table 3]

We first discuss the comparison between Yamada (1991) and this study. Yamada (1991) estimates two patterns of data—stock and flow—as input quantities for labor, capital, and land, which are then used to measure TFP. Table 3 exemplifies both of these patterns.

We compare the two estimation approaches during the period from 1965 to 1985. As a whole, the average annual growth rate of TFP is almost the same. However, significant divergences in the growth rate become evident when we examine each five-year period in isolation. This is particularly true for 1965 to 1970. This difference derives from the growth rate for capital and intermediate inputs and differences in their factor share. Yamada (1991) calculates land input value by multiplying the total land value by 8%, resulting in a value that is higher than in this study, while the factor share of capital and intermediate inputs becomes smaller. Therefore, the total input growth rate is low in Yamada (1991) and high in this study, resulting in the TFP growth rate being high in Yamada (1991) and low in this study. Hayami and Godo (2002) simply extrapolated the stock term estimates in Yamada (1991), with the TFP annual growth rate for the period of 1980 to 1995 being 1.5%. Since the estimated value in this study is 1.37%, the values are largely equivalent for this period.

Next, we compare the estimated results in this study with the TFP growth rates presented in JIP 2015 and JIP 2018. JIP 2015 covers the period of 1970 to 2012, while JIP 2018 covers 1994 to 2015[10]. The annual average growth rate for the period of 1970 to 2011 varies significantly between JIP 2015 and this study; it is 0.16% in JIP 2015, while it is 1.20% in this study. Further, for the period of 1994 to 2011, an average annual growth rate of 1.31% is observed in this study, compared to 0.60% in JIP 2018 and -0.45% in JIP 2015. This is because JIP 2015 reflects the high rate of increase in the accumulation of public works investment, which are included in the

10 In JIP 2015, the agricultural sector is defined to include the rice and wheat producing industry, other crop agriculture, livestock, sericulture, and agricultural services, while in JIP 2018, it considers agriculture and agricultural services alone. We calculated the output index based on JIP 2015 and 2018 using nominal output values as the weight.

data for agricultural sector capital, but it does not include the downward-trending land input within its production factors, thus leading to the low TFP growth rate. Since JIP 2018 excludes public works investment, the TFP growth rate calculated in the subsequent study is higher than in JIP 2015.

5. Conclusion

In this study, we presented a method of calculating aggregated macro statistics for Japanese agriculture, which considers the methodological improvements from previous studies such as Izumida (1987), Yamada (1991), and Kuroda (1995) in terms of labor and capital. Then, we produced estimates for Japanese agricultural output, labor, capital, land, and intermediate inputs data for the period of 1963 to 2011. Further, Törnqvist indexes were aggregated for total output and total input, with the TFP growth rate estimated as the difference in growth rates.

The estimation results in this study show that TFP rises continually in the post-war period. They also indicate that the underlying factors have been changing since the mid-1980s. We presented the hypothesis that technological progress was the source for TFP growth in the period from 1963 to 1985, while the withdrawal of producers with relatively low productivity is linked to the rise in TFP in the latter period from 1985 onwards.

The remaining issues for future research to consider include clarifying the factors that contribute to improved productivity that are measured as TFP growth. It is necessary, for example, to measure improvements in the quality of factors of production and use the results in a growth accounting analysis. In this study, age of labor is considered in the *Survey of the Farm Household Economy*, but it is also necessary to incorporate the effects of education and evolving forms of employment in considering the quality of labor. Estimating capital quality requires considering improvements in the performance of agricultural machinery or the selective breeding of fruit trees. Takayama (2009) provides some insight on quality control for tractors and cultivators, but it is necessary to expand quality control to other capital goods. For land quality, soil characteristics and access to large cities, as well as improvement through public works investment should be considered. Akino (1979) provides a basis for this analysis by exploring the impact of land improvement projects on growth in agricultural output. It is also necessary to examine the impact of technological research and education on agricultural productivity, as studied by Kuroda (1997). Considering how these factors are linked to the improvement of agricultural productivity is meaningful in terms of both the empirical analysis itself and the potentially significant policy implications, which can be derived to improve productivity in agriculture.

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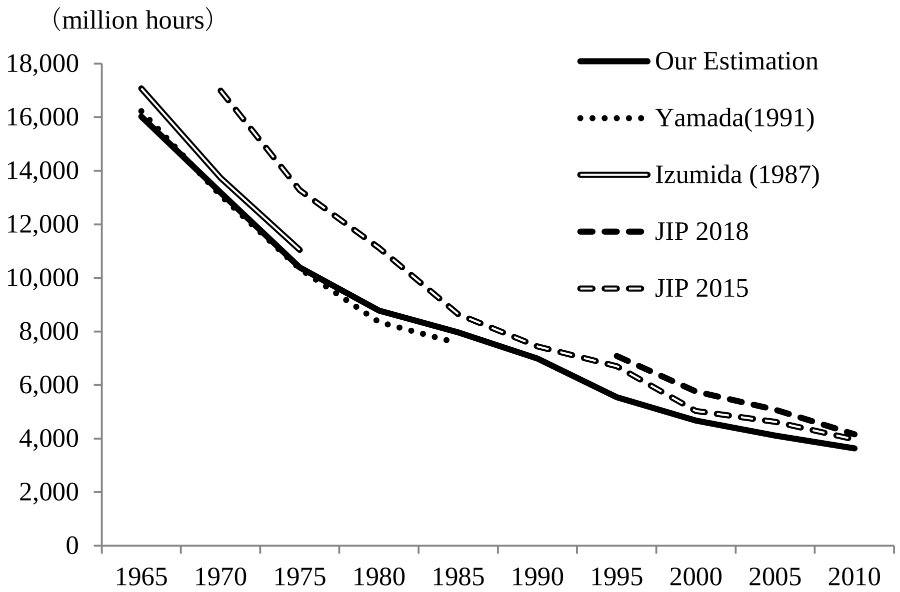


Note. The simple sums of hours worked by sex are showed.

Figure 1. Labor Input Hours

Note: Simple total for labor hours by gender

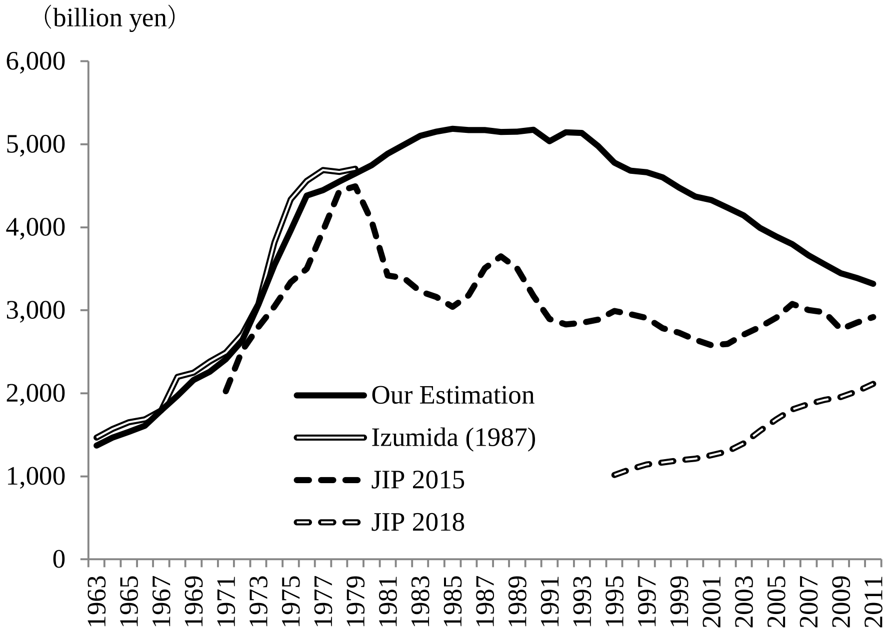
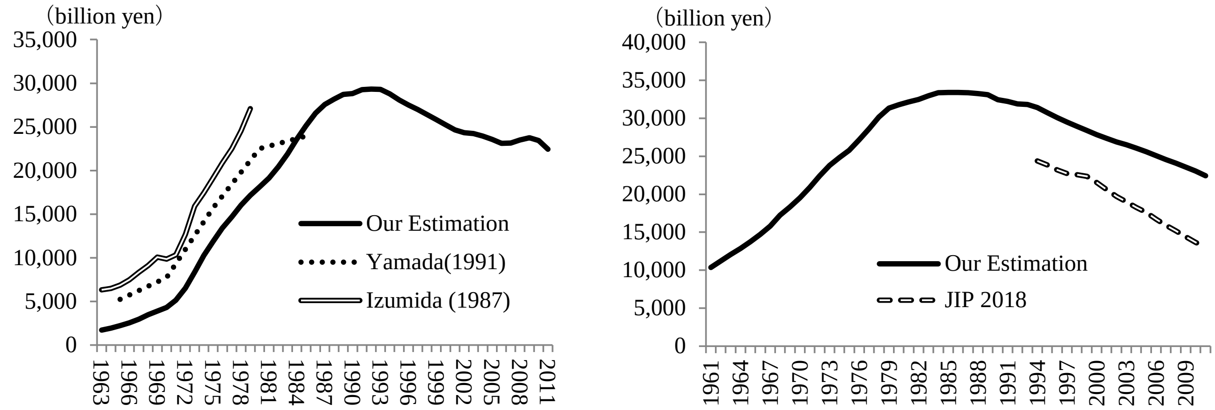


Figure 2. Nominal Labor Input Values



price at 1975 price at 2000

Figure 3. Real Capital Stock

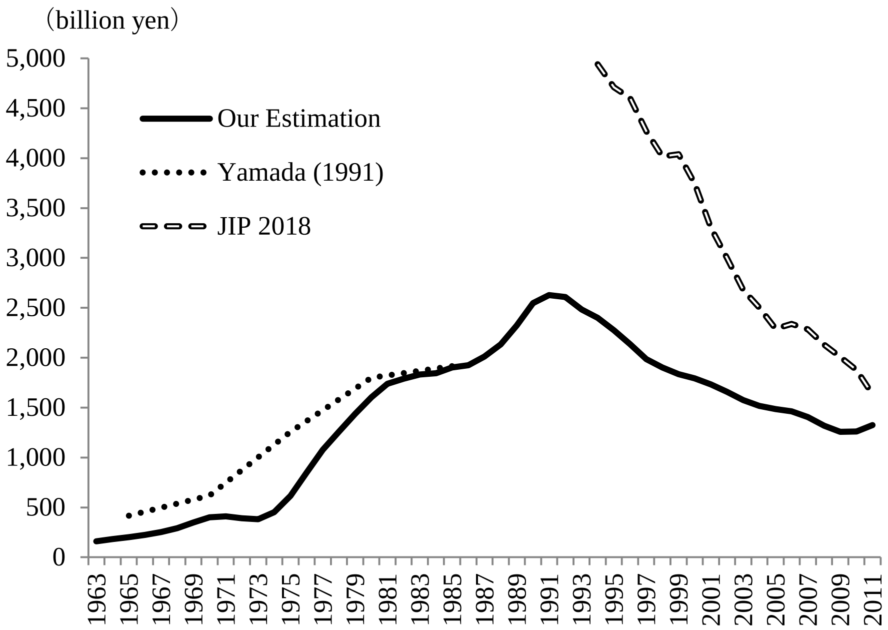


Figure 4.　Nominal Capital Input Values

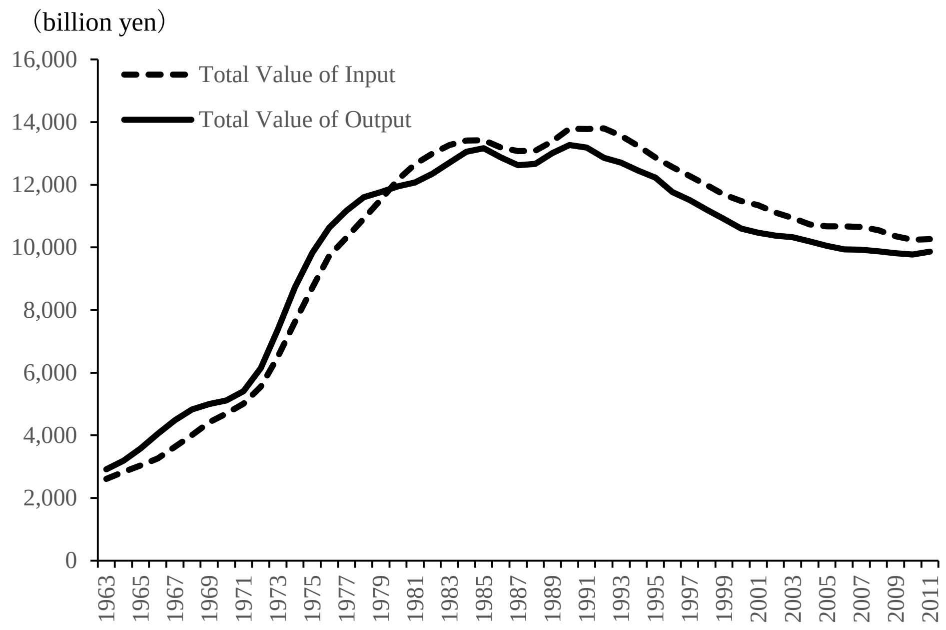


Figure 5. Nominal Input Value and Nominal Output Value

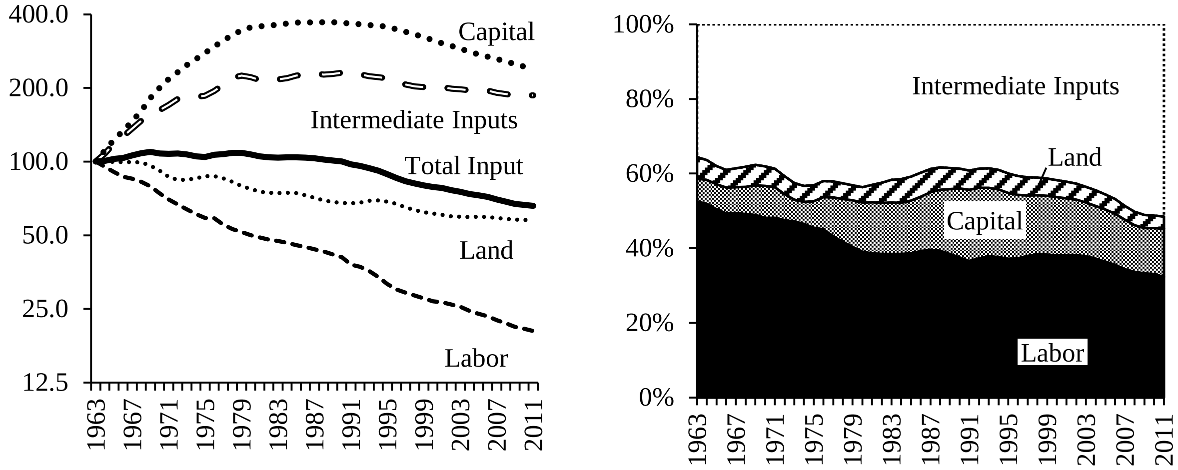


Figure 6. Factor Input Index and Factor Share

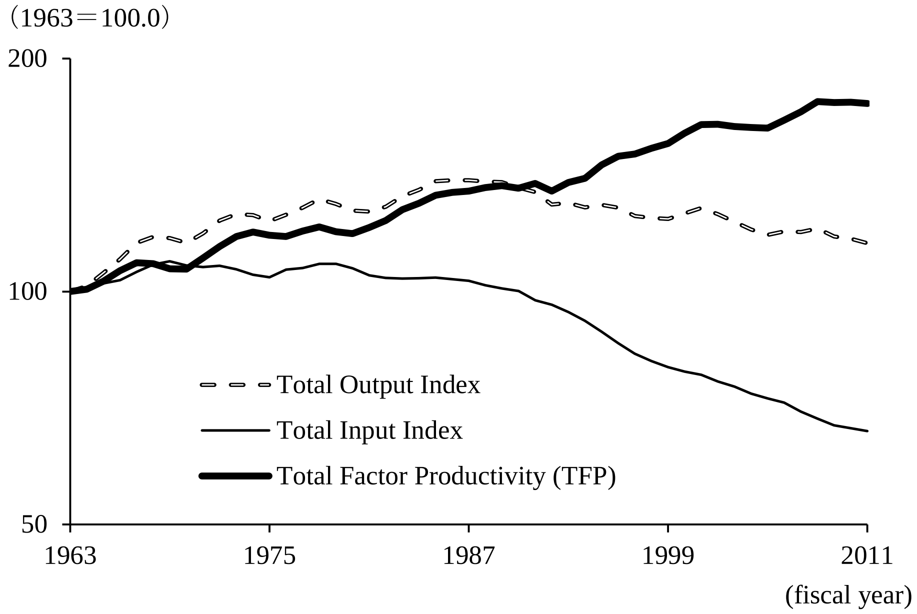


Figure 7.　Total Output Index, Total Input Index, and Total Factor Productivity

Table 1. Growth Accounting of Agricultural Production (yearly average)

	Fiscal Year	Total Output	Total Input	Labor	Land	Capital	Inter-mediate Inputs	TFP
Entire Period	1963-2011	0.30%	-0.87%	-1.38%	-0.06%	0.08%	0.49%	1.17%
Former Subperiod	1963-1985	1.49%	0.19%	-1.65%	-0.07%	0.47%	1.44%	1.30%
Latter Subperiod	1985-2011	-0.71%	-1.76%	-1.15%	-0.05%	-0.25%	-0.30%	1.05%
Former Subperiod	1963-1970	2.07%	1.12%	-2.14%	-0.07%	0.70%	2.61%	0.95%
	1970-1975	1.30%	-0.71%	-2.19%	-0.06%	0.46%	1.08%	2.02%
	1975-1980	0.62%	0.53%	-1.36%	-0.10%	0.50%	1.49%	0.09%
	1980-1985	1.76%	-0.54%	-0.72%	-0.04%	0.12%	0.10%	2.30%
Latter Subperiod	1985-1990	-0.39%	-0.80%	-0.90%	-0.11%	0.00%	0.21%	0.41%
	1990-1995	-1.02%	-2.42%	-1.89%	0.01%	-0.15%	-0.40%	1.40%
	1995-2000	-0.51%	-2.38%	-1.22%	-0.11%	-0.41%	-0.65%	1.87%
	2000-2005	-1.27%	-1.59%	-0.89%	-0.03%	-0.40%	-0.28%	0.32%
	2005-2011	-0.42%	-1.63%	-0.92%	-0.02%	-0.30%	-0.38%	1.21%

Note: The breakdown of total input is calculated based on the contribution of each growth rate, multiplied by the factor share.

Table 2. Contribution to Total Output Growth (yearly average)

	fiscal year	Total Output	Rices	Vege-tables	Fruits	Other Crops	Livestock Products	Agricultural Services
Entire Period	1963-2011	0.30%	-0.22%	0.01%	0.03%	-0.06%	0.49%	0.05%
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Former Subperiod	1963-1985	1.49%	-0.21%	0.29%	0.19%	0.06%	1.14%	0.02%
Latter Subperiod	1985-2011	-0.71%	-0.22%	-0.22%	-0.11%	-0.16%	-0.06%	0.07%
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Former Subperiod	1963-1970	2.07%	-0.31%	0.45%	0.34%	-0.22%	1.69%	0.12%
	1970-1975	1.30%	0.21%	0.16%	0.35%	-0.07%	0.74%	-0.09%
	1975-1980	0.62%	-1.09%	0.15%	-0.07%	0.33%	1.30%	-0.01%
	1980-1985	1.76%	0.41%	0.34%	0.08%	0.31%	0.61%	0.02%
Latter Subperiod	1985-1990	-0.39%	-0.66%	-0.31%	-0.09%	0.06%	0.49%	0.11%
	1990-1995	-1.02%	0.40%	-0.29%	-0.38%	-0.35%	-0.43%	0.03%
	1995-2000	-0.51%	-0.61%	-0.13%	0.12%	0.17%	-0.13%	0.07%
	2000-2005	-1.27%	-0.47%	-0.41%	-0.08%	-0.32%	-0.10%	0.11%
	2005-2011	-0.42%	0.15%	-0.03%	-0.13%	-0.33%	-0.11%	0.03%

Note: Growth rate of output quatities are multiplied by share accounting for the output value.

Table 3. Comparison of Yearly Average Growth Rate by TFP Period

	Our	5 yr	Yamada (1991)		JIP	
year	Estimation	average	Stock	Flow	2015	2018
1965-1985	1.28%	1.20%	1.26%	1.40%	-	-
1970-1985	1.47%	1.25%	1.19%	1.18%	1.34%	-
1970-2011	1.20%	-	-	-	0.16%	-
1994-2011	1.31%	-	-	-	-0.45%	0.60%
1965-1970	0.72%	1.06%	1.46%	2.07%	-	-
1970-1975	2.02%	1.59%	1.57%	1.18%	3.79%	-
1975-1980	0.09%	0.37%	0.41%	1.11%	-1.48%	-
1980-1985	2.30%	1.78%	1.61%	1.24%	1.70%	-
1985-1990	0.41%	0.65%	-	-	0.49%	-
1990-1995	1.40%	1.21%	-	-	-2.70%	-
1995-2000	1.87%	1.92%	-	-	0.55%	2.75%
2000-2005	0.32%	0.71%	-	-	-1.23%	-1.73%
2005-2011	1.21%	-	-	-	0.14%	1.17%