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Effects of Aggregate Shocks on the Productivity of Farm Households in Prewar Japan

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An economic crisis can be considered as a man-made disaster with the characteristics as an aggregate shock, thus complicating and hindering mutual insurance or help in local communities. This paper investigates the dynamics of productivity in prewar rural Japan and examines which farm households were more vulnerable to the Great Depression, as a representative example of aggregate shocks that have a serious impact on rural sectors. First, using panel data from farm households collected by the Imperial Agricultural Association (*Teikoku Nokai*), we measured the Malmquist productivity index (MPI) and decomposed it into technical change and efficiency change for the period of 1924–1933. Second, with this panel data, we investigated which farm households were more vulnerable to aggregate shocks. Our main findings are as follows. First, although the MPI declined rapidly after the Great Depression due to the technical and efficiency change, this rapid decline in productivity was temporary. Second, the vulnerability of farm households to aggregate shocks differed by region, and large-scale farmers were relatively robust to them. These differences in vulnerability across farm size may have triggered the structural changes in Japan's prewar agriculture after the Great Depression. Our findings shed light on the dynamics of farm household behavior in prewar Japan from the micro and quantitative perspectives.

Key words: Malmquist productivity, prewar Japan, aggregate shock, the Great Depression

1. Introduction

Man-made and natural disasters such as global economic crises and heavy earthquakes have the characteristics of aggregate shocks, which makes mutual insurance and insurance in the local area difficult. Such aggregate shocks have more serious consequences in developing economies, where various markets, including insurance markets, are incomplete. During the development stage of prewar Japan, the global depression triggered by the plunge in stock prices in the United States in October 1929, led to the lifting of the gold ban and a decline in silk thread prices due to weak silk thread exports. Subsequently, in October 1930, the price of rice collapsed. This was partly due to a bumper harvest. These events had huge impacts on the rural economy of Japan, and are known as the Showa depression (Hayashi, 2003). Inomata (1934) recorded

the situation of rural areas during this depression. The reportage states that many farmers had large debts, and the circumstances were such that they had to cease the use of fertilizers and recurrent goods.

There is an extensive literature on farm households during the Showa depression, mainly in the fields of agricultural and economic history (for example, Ouchi, 1960; Kurihara, 1974). They note the robustness and stability of middle-scale farmers. In addition, the Showa depression is considered to be the trigger for the decomposition of farmer classes in the inter-war period. However, most of these studies are qualitative analyses based on historical materials. In recent years, some studies have been published that use econometric analysis of the inter-war period microdata before and after the Showa depression. Examples of such research include: Saito (2009), who examined the relationship between the members in farm households and labor

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supply using the micro data from *the Survey of Farm Household Economy (SFHE)*; Arimoto (2012), who evaluated the impacts of the economic rehabilitation movement; Arimoto and Sakane (2008), who investigated the causes of tenancy disputes; and Arimoto *et al.* (2013), who constructed farmer microdata on farmers' debt after the Showa depression.¹⁾

In addition, Fujie and Senda (2011) examined the coping behaviors of farm households against aggregate shocks due to the Showa depression by using farm panel data from the decade around the depression, 1924 to 1933. They suggested that farm households coped with the depression using strategies such as adjustment of employment labor, arable land area, and fertilizer inputs. Also, Ozeki and Sato (2008) investigated the characteristics of the *SFHE* in the prewar period and described the significance of a comparative study of farm households in prewar Japan and modern developing countries. Thus, previous literature on farm households in prewar Japan can provide insights for a comparative study of farm households in developing countries' economies.

Yamada (1963) and Hayami (1973) are representative of the literature that uses aggregate data from the inter-war period. They used *the Long-term Economic Statistics (LTES)* edited by Ohkawa *et al.* (1966). According to Hayami (1973), the overall productivity, labor productivity, and land productivity (annual) growth rates from 1900–1920 in the agricultural sector were 2.0%, 2.6%, and 1.3%, respectively, while from 1920–1935, they were 0.9%, 1.1%, and 0.8%, respectively. He evaluated the inter-war period in which the Showa depression occurred, to be a period of stagnant agricultural growth. Hayami (1973) found that the exhausted potential of conventional technology, such as Meiji farming methods, and the deterioration in market conditions for agricultural products caused this stagnation. Minami (2002) also found that the slowing of agricultural growth during the period caused the regional changes in rice cultivation.

Furthermore, in the field of development economics, some literature published in recent years investigate the coping behaviors of households against aggregate shocks like natural and man-made disasters such as tsunami and financial crises. For example, there are several studies that addressed the financial crisis in

Argentina and the currency crisis in Indonesia. These studies have shown that households adjusted their labor supply, reduced education and medical expenditures, and relocated income as ex-post-facto coping behavior to cope with the currency crisis (Fallon and Lucas, 2002; Kang and Sawada, 2009; McKenzie, 2003, 2004; Ravallion and Lokshin, 2007; Smith *et al.*, 2002). Several studies also clarified farm households' coping strategies when faced with aggregate shocks due to natural disasters and their vulnerability or robustness to these shocks (Kurosaki, 2009, 2011; Sakurai, 2006; Sakurai *et al.*, 2011; Sawada, 2007; Sawada and Shimizutani, 2008; Sawada *et al.*, 2011; Shoji, 2008).²⁾ Nonetheless, Barrett *et al.* (2006) is one of the few studies that examined the effects of aggregate shocks on farm-level production behavior. Using plot-level data, Barrett *et al.* (2006) found that the technical efficiency of rice farming temporarily declined due to the shock caused by the devaluation of Côte d'Ivoire's currency.

Despite the accumulation of the above literature, what is missing is a study at the micro level on the effects of the Showa depression on the productivity of farm households. Arimoto *et al.* (2013) indicated that many of the owner-cum-tenant farmers in the 1930s after the Showa depression may have been subject to credit constraints. These constraints may have led to a decline or stagnation in the productivity of farm households after the depression through a reduction in agricultural investment or factor inputs. Additionally, as Fujie and Senda (2011) suggested, if farm households coped using strategies such as reducing the recurrent goods, adjusting hired labor or their arable land area and fertilizer inputs, did the productivity of farm households decline due to this adjustment of factor inputs? Furthermore, how was a farm household vulnerable to the depression in terms of its productivity? Some literature on agricultural productivity and agricultural growth in the prewar and inter-war periods consist mainly of macro-perspective studies using aggregate data, such as *LTES*. To the authors' knowledge, no existing research has examined the effects of the depression on production behavior or productivity using the household-level micro data.

Therefore, this paper measures the productivity of farm households in prewar Japan using the micro panel

1) In addition to this literature, Kusadokoro *et al.* (2012) investigated the asset accumulation behavior of farm households and Kusadokoro (2012) examined the existence of scope economy through the estimation of the output distance function using panel data from the *SFHE*.

2) In addition to these studies, for example, Dercon (2005) is a representative work on household coping behaviors to cope with shocks in developing countries, and Sawada (2010) is a survey article on household coping behaviors when faced with aggregate shocks such as man-made and natural disasters.

data from the *Survey on Farm Management (SFM)* conducted by the Imperial Agricultural Association (*Teikoku Nokai*) from 1924 to 1933. We also investigate the vulnerability and robustness of farm households against the Showa depression as an aggregate shock. Although farm income and land productivity are representative indicators of productivity, if productivity indicators such as farm income are used in panel data, the trend in these indicators represents a mixture of the effects of both technological progress and income improvement, and it is difficult to grasp these effects separately. Thus, this paper adopts the Malmquist productivity index (MPI). Malmquist productivity can handle the multiple input/output relationships and separate the effects of technological progress and changes in technology efficiency over time in panel data.

The rest of this paper is organized as follows. The next section describes the summary and the characteristics of the data used for analysis. Section 3 reviews the trends in agricultural product prices and farm income before and after the Showa depression. In section 4, we describe the method for measuring the Malmquist productivity of farm households and how the data can be used for measurement. It also shows the dynamics of Malmquist productivity. In section 5, we conduct a panel data analysis using the Malmquist productivity obtained in the previous section. We also investigate the determinants of household productivity and the vulnerability and robustness of farm households against aggregate shock in the inter-war period using Malmquist productivity. The results and interpretation are discussed. Finally, a summary and conclusion are provided.

2. Data³⁾

This paper uses the *SFM* implemented by the Impe-

rial Agricultural Association (*The Imperial Agricultural Association Survey; IAAS*). The *IAAS* was a follow-up survey of farmers that was conducted by the Imperial Agricultural Association and prefectural agricultural associations from 1924 to 1933. The aim of the *IAAS* was as follows. "... First of all, with regard to many cases of farm management, we observe changes in the conditions of farm management from various perspectives over a prolonged period of time, and we need to clarify how such changes affect farm management." Thus the *IAAS* was carried out to clarify the dynamics of farm management and behavior during a specific time period.⁴⁾

The *IAAS* comprises the "*Survey on the Dynamics of Farm Management (Farm Management Results Survey Report: 2nd Report)*" (published in 1936, hereinafter *SDFM*), the "*Survey on the Dynamics of Farm Management during a Recent Ten-Year Period*" (published in 1934, hereinafter *Ten-Year Survey*), and an errata table. We revised the original data from the *Ten-Year Survey* to incorporate the information on the errata table and combined this with the *Ten-Year Survey* and *SDFM* data. We use this combined survey data because the *Ten-Year Survey* has rich information on agricultural production, such as cropping areas and yields at the item level, and the *SDFM* includes 40 items that it shares with *Ten-Year Survey*. Therefore, the two surveys can be used in a mutually complementary manner.⁵⁾

Major survey items in the *IAAS* include the cultivated area, agricultural working days, the cultivated area by each crop, farm income and expenditure. The primary crops of the farm households covered by the *IAAS* vary, including items such as rice cultivation, sericulture and fruit trees. In the *IAAS*, farm households are classified into three categories according to the size of their arable land: large (more than 10 hec-

3) The description of this section is based on Fujie and Senda (2011).

4) There is also the *SFHE* carried out by the Ministry of Agriculture and Forestry in the same period. However, as shown in Inaba (1953) and Ozeki and Sato (2008), the *SFHE* is divided into four periods: the first (1921–1923), second (1924–1930), third (1931–1941), and fourth (1942–1948). The survey method and criteria for selecting samples is different in each period. In the second and third periods, which are the period of analysis for this paper, the bookkeeping structure of the survey forms and the surveyed farm households are different. For this reason, the *SFHE* cannot be used as panel data before and after the Showa depression. Meanwhile, the *IAAS* has secured the same survey items and sampled farm households over 10 years, and *IAAS* can therefore be used as panel data covering the period of the depression. For this reason, we decided to use *IAAS* in this paper.

5) The data in the *SDFM* differs from the *Ten-Year Survey* used by Fujie and Senda (2011) in terms of the farm households surveyed and the summary items in the interim tabulation. First, concerning the surveyed farm households, *Ten-Year Survey* only has data on the 40 farm households who continued the survey for the 10 years from 1924 to 1933. The *SDFM* has an intermediate tabulation of the 107 farm households continuing for more than five years. The number of tabulated items in each survey varies, from 103 in *SDFM* to 487 in *Ten-Year Survey*. The difference in the number of items is due to the fact that many items, including the detailed cropping areas and yields at the item level, are included in *Ten-Year Survey*. Homing in on items that are related to major expense items and management balances, there are 40 items in common.

tares), medium (more than 2 hectares but less than 10 hectares), and small (less than 2 hectares). The farm households surveyed in each prefecture were set to be one medium and two small farm households or one large farm household. The follow-up surveys were generally conducted on the farm households surveyed, but sample attrition and category changes in the course of the follow-up surveys were permitted. Depending on the survey year of the *IAAS*, the number of surveyed farm households varies. From 1924 to 1933, 43 farm households are available with balanced panel data. Of these 43 farm households, this paper uses the balanced panel data of 39 farm households, excluding 4 that do not contain information on the farm gate price, which is required for analysis.⁶⁾ The geographical distribution of the farm households are as follows; Tohoku: 8, Kanto: 6, Hokuriku: 3, Tokai: 5, Kinki: 7, Chugoku: 4, Shikoku: 4, and Kyushu: 2. As noted by Senda and Kusadokoro (2009), the households in the *IAAS* tend to be biased toward highly skilled middle- and large-scale farmers. In addition, because the *IAAS* was originally designed to be a survey that also serves as bookkeeping guidance, the data from the households may also reflect the effects of improvements in management through bookkeeping guidance.

Although it is necessary to heed the above points, the *IAAS* has high material value for clarifying the production behavior and productivity of farm households during the Great Depression. In addition, this survey provides panel data of farm households during the prewar period, including the Showa depression. The survey period of *IAAS* is assumed to be from February 1 to the end of January the following year. We conducted the analysis that follows based on this division of years.

3. The Showa Depression and Farm Households

Table 1 shows the trends of farm gate prices (nominal prices) of brown rice and spring cocoons during 1924–33, using the balanced panel data of *IAAS*. The table shows that the price of rice fell greatly, from 27.8 yen/*koku* in 1929 to 17.9 yen/*koku* in 1930. This indicates that farm households faced a rapid drop in the price of rice due to the Showa depression.⁷⁾ This table also shows that the price of cocoons fell dramatically

Table 1. Trends in farm gate prices of brown rice and spring cocoons

Year	Brown rice (yen/ <i>koku</i>)	Spring cocoons (yen/ <i>kan</i>)
1924	39.7	7.6
1925	38.0	11.4
1926	34.4	9.3
1927	31.2	7.2
1928	27.9	7.0
1929	27.8	7.7
1930	17.9	4.1
1931	18.4	3.3
1932	20.7	2.8
1933	21.1	6.1

Source: Teikoku Nokai. *The Survey on the Dynamics of Farm Management*.

Notes: 1) Farm gate prices represent the sample mean.

2) 1 *kan* = 3.75 kg, 1 *koku* = approx. 150 kg.

Table 2. Trends in the number of working days of hired labor

(unit: day)

Year	Paddy rice	Sericulture	Total
1924	34.8	7.3	42.1
1925	41.0	9.5	50.5
1926	41.8	18.1	59.9
1927	43.4	15.2	58.5
1928	49.5	14.5	64.1
1929	50.1	12.7	62.8
1930	47.6	13.8	61.4
1931	49.4	8.8	58.2
1932	53.7	7.2	60.9
1933	57.3	10.9	68.2

Source: Teikoku Nokai. *The Survey on the Dynamics of Farm Management during a Recent Ten-Year Period*.

with the depression. Until 1932, the cocoon price continued to decline by about 64% from 7.7 yen/*kan* in 1929 to 2.8 yen/*kan* in 1932,⁸⁾ while the rice price increased after 1931. Table 2 represents the trend in the number of working days of hired labor. This table shows that the total number of working days decreased only slightly; it did not exhibit a major change, although the number of working days in sericulture de-

6) The number of farm households surveyed in each year is as follows; 1924: 107, 1925: 107, 1926: 107, 1927: 106, 1928: 107, 1929: 95, 1930: 79, 1931: 71, 1932: 58, and 1933: 44. Appendix 1 shows the location of the surveyed farm households used in this paper, and Appendix 2 shows the comparison between the excluded sample (the dropped sample) for construction of a balanced panel data and the sample used in this paper. Appendix 2 indicates that there are not clear differences between the dropped sample and the sample used for the rice income ratio, sericulture income ratio, or location. However, for any year, the ratio of owner-cultivators in the dropped sample is about 10% lower than the sample used, and the arable land area is about 10 *tan* larger. This indicates that sample attrition may have occurred mainly among relatively large owner-cum-tenants.

creased after the depression.

The trend in the ratio between the price of fertilizer and that of rice is shown in Figure 1. The figure shows that this relative price ratio sharply declined from 1929 to 1930 after the depression. This indicates that the fall in rice prices was relatively greater than that in the fertilizer prices during the depression, and the situation surrounding agricultural production deteriorated due to the expansion of the *Schere* (a scissors-form difference in prices). It is expected that this expansion of the input/output price difference would lead farm households to forgo fertilizer purchases and increase self-provided fertilizer. Hayami (1963) showed that the amount of fertilizer input decreased by 2.70% per annum from 1929 to 1933 during the agricultural depression, while the amount of self-provided fertilizer input increased by 3.89% per annum during the same period. The rate of increase of self-provided fertilizer input during the agricultural depression reached its highest value during the prewar measurement period (1883–1939). In addition, Fujie and Senda (2011) suggested that the shock caused by the depression led to a reduction in the value of fertilizer input, which may have caused the stagnation of productivity in the prewar period.

As described above, the sharp decline in agricultural product prices caused by the aggregate shock of the Showa depression and the expansion of the input/output price ratio may have led to reduce fertilizer inputs due to the farm households forgoing investments in purchased fertilizer and the substitution of self-provided fertilizer for purchased fertilizer. This may have caused a decline in productivity through changes in the composition of the fertilizer and a deterioration in the quality of the fertilizer. In addition, sharp falls in silk thread prices resulted in the shrinkage of and exits from sericulture, and this led to allocation of surplus

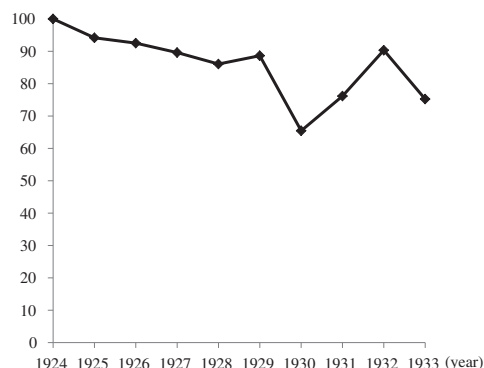


Figure 1. Trend of relative ratio of fertilizer price and rice price (1924 = 100)

Source: See Table 1.

Note: Fertilizer price is the mean of the gate price of ammonium sulfate, potassium sulfate and caustic lime.

labor in households to rice farming, which could have led to a decline in productivity. In addition, the rapid changes in the economic environment produced coping behaviors in farm households involving adjustments in land use, non-farm labor, hired labor and the use of fertilizer input (Fujie and Senda, 2011). Thus farm households reduced productivity temporarily if they could not cope smoothly with the aggregate shocks and it took time for them to adjust to an optimal use of input factors and their efficient allocation.

Table 3 shows farm income, farm income per working day, and farm income per arable land area during 1924–33. From 1929 to 1930, farm income sharply declined by about 60% from 1,491 yen to 890 yen due to the rapid fall in the rice price caused by the 1930 depression. In addition, the coefficient of variance of farm income dramatically increased from 39% in 1929 to 61% in 1930. This suggests that the disparity in farm

7) The *SDFM* does not include the monthly farm gate price. However, the *IAAS* was a survey conducted as part of the Agricultural Management Improvement Project, which was a survey designed for bookkeeping records and improvement of management through their use (Tama, 1986). Therefore, if bookkeeping was carried out properly, transactions of rice and silk threads would have been recorded every day, and it is presumed that an annual weighted average price based on trade volume was adopted as the farm gate price of farm households. For example, for the farm gate price of rice in 1930, the shipment of rice was mainly from October to November, so the farm gate price was likely to mostly reflect the current prices at that time. Therefore, we infer that the rice price for each year strongly reflected the price immediately after the harvest. According to Kayo (1977), the official Tokyo Fukagawa rice price from September to November 1930 was 28.7 yen (Sept.), 19.1 yen (Oct.) and 18.1 yen (Nov.); therefore, the October/November price level was close to the *IAAS*'s 1930 farm gate price (brown rice) of 17.9 yen. Likewise, because the price of spring cocoons reflected the 1930 trading price, the price reflected the effects of the decline in silk prices due to the Great Depression in October 1929. These indicate that the 1930 farm gate price shown in this paper roughly reflects the price level after the depression. In addition, it has been noted that a bumper rice harvest in 1930 accelerated the collapse of the rice prices. Regarding this bumper harvest, the yield of paddy rice increased by about 10% from 2.78 *kokutan* in 1929 to 3.07 *kokutan* in 1930. This indicates that 1930 was a bumper harvest. Furthermore, according to Sakane (2010), using Umemura *et al.* (1966), the average annual yield was 1.88 *kokutan* from 1926–1935. These facts also indicate that the productivity and technical level of the surveyed farm households in this paper were high on average.

Table 3. Trends in farm income and related items

Year	Farm income (yen)		Farm income/Working days (yen/person*day)		Farm income/Arable land area (yen/tan)	
1924	1,651	(47)	1.75	(52)	86.6	(44)
1925	1,897	(37)	2.03	(41)	99.4	(34)
1926	1,694	(46)	1.82	(47)	82.7	(41)
1927	1,511	(40)	1.71	(46)	75.9	(42)
1928	1,555	(39)	1.68	(45)	77.5	(38)
1929	1,491	(39)	1.59	(43)	74.0	(40)
1930	890	(61)	0.94	(57)	43.4	(56)
1931	911	(45)	0.96	(45)	45.0	(47)
1932	1,072	(42)	1.16	(47)	52.5	(43)
1933	1,276	(34)	1.35	(42)	62.5	(41)

Source: See Table 1.

Notes: 1) Figures in parentheses represent the coefficient of variance.

2) 1 tan = approx. 0.1 hectare.

income expanded among farm households after the depression.

Furthermore, farm income per working day and farm income per arable land area declined greatly in 1930 after the depression.⁹⁾ However, it is important to note that the figures in the table are the aggregate result of the various main crops of farm households, and if farm income per working day and farm income per arable land area are considered to be proxy indicators of labor productivity and land productivity, respectively, labor and land productivity greatly declined after the Showa depression. From 1929 to 1930, the coefficient of variance of labor productivity increased from 43% to 57%, and land productivity increased from 40% to 56%, showing a rapid increase not observed prior to 1929. The increase in the coefficient of variance suggests that disparities in labor productivity and land productivity among farm households expanded after aggregate shocks due to the depression. These

results indicate that some vulnerable farm households faced a rapid reduction in productivity due to aggregate shocks caused by the Showa depression, while other robust households did not face such a large drop. What farm households were vulnerable to aggregate shocks and fell in productivity?

However, in considering the effects of aggregate shocks on the agricultural production of farm households, most of the surveyed farm households worked in both rice farming and sericulture.¹⁰⁾ Therefore, a method of measurement that can address multiple outputs is required to measure productivity. In addition, there are productivity indices that show labor productivity and land productivity, such as farm income per working days or the arable land area, which were examined in Table 3. However, the trends of these indicators include both technological progress and technological efficiency changes, and we cannot distinguish between them.

8) Regarding the different price dynamics in each region, we examined the rice price in eastern Japan and western Japan separately. As a result, although not shown in the figure, the rice price for western Japan exceeds prices in eastern Japan with differences from 0.6 yen/koku to 2.0 yen/koku and this shifts almost in parallel. This relationship does not change before or after the depression. Regarding the cocoon price, although the price in western Japan exceeds that in eastern Japan for many years, the price difference is 0.63 yen/kan at the most (in 1930), and the price difference moves in parallel. This relationship did not change before and after the depression. Furthermore, the coefficient of variance of the farm gate price of rice and cocoons was calculated to examine the differences among the farm households regarding the farm gate price. Although the table has been omitted, the coefficient of variance of the rice price was stable, except in 1930. On the one hand, the coefficient of variance in 1930 was 19.2%, which was particularly high. This indicates that the difference in the farm gate price among farm households expanded during the depression. On the other hand, the coefficient of variance for spring cocoons remained at a high level of 11.2% on average from 1924 to 1933, and, although it showed a downward trend from 1924 to 1929, there was a rapid increase in 1930, and this upward trend continued from 1931 onward. This shows that differences in the cocoon price among farm households expanded, and this divergence continued after the depression.

9) As noted in footnote 7, most farm revenue used for calculating farm income consists of the rice and cocoon price in October 1930, after the decline. For this reason, farm income in 1930 is considered to represent the level after the depression.

10) In addition to rice farming, all the farm households surveyed were producing other crops, such as sericulture.

Therefore, we measure Malmquist productivity to clarify the productivity of farm households. Malmquist productivity can measure the productivity of objects producing some farm products using multiple inputs, and separate technological progress and technical efficiency change (Caves *et al.*, 1982). In recent years, Malmquist productivity has been used in much of the previous literature (e.g., Umetsu *et al.*, 2003; Zhengfei and Lansink, 2006; Yamamoto *et al.*, 2007). It has the advantage of not depending on the form of the cost or production function. In addition, Malmquist productivity can be decomposed into technological change, which shows shifts in the production frontier, and efficiency change, which approaches the production frontier. Therefore, by using Malmquist productivity, we can clarify that the aggregate shock affected which of the factors that form productivity. In the next section, we measure the trend in Malmquist productivity, technological change, and efficiency change in farm households in prewar Japan. We also investigate the determinants of Malmquist productivity and the vulnerability of farm households against aggregate shocks caused by the depression using Malmquist productivity.

4. Productivity of Farm Households in Prewar Japan

1) Measuring the productivity of farm households using Malmquist productivity¹¹⁾

The Malmquist productivity index (MPI) is an index proposed by Malmquist (1953) which Caves *et al.* (1982) extended that represents the change in productivity between two periods, $t-1$ and t . We call this “Malmquist productivity” or “productivity change.” Färe *et al.* (1994) showed that Malmquist productivity can be decomposed into technological change (TC) and efficiency change (EC). We describe the concept of Malmquist productivity below and present the decomposition of TC and EC in Malmquist productivity in Figure 2.

Consider a farm household with an A_1 input/output relationship in the $t-1$ period. The line OBC represents the constant returns to scale of the production frontier.¹²⁾ Here, based on the input amount, the productivity of the farm household is represented by $Y_1B/$

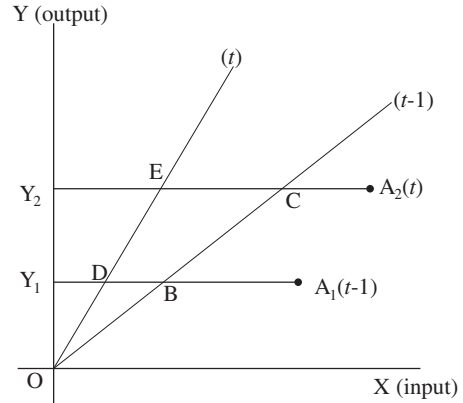


Figure 2. Malmquist productivity and technological/efficiency change

Y_1A_1 . In this figure, since Y_1B/Y_1A_1 is less than 1, it shows a loss of productivity compared to the most productive farm household.¹³⁾ If A_1 is on the frontier, the productivity of the farm households is the maximum and equal to 1.

Next, from the period $t-1$ to t , the production of the farm household moves from A_1 to A_2 and the production frontier also shifts to ODE. Changes in the productivity of farm households can be measured as the ratio of the data envelopment analysis (DEA) score in the period $t-1$ to the DEA in period t calculated by DEA assuming constant returns to scale, while the frontier is also shifting. Thus, the MPI of farm households from the period $t-1$ to t is defined by the geometric mean of the ratio of the two production frontiers in the same period (Equation (1)).

$$MPI[t-1, t] = \left(\frac{Y_2C/Y_2A_2}{Y_1B/Y_1A_1} \frac{Y_2E/Y_2A_2}{Y_1D/Y_1A_1} \right)^{\frac{1}{2}} \quad (1)$$

Here, if $MPI > 1$, Equation (1) shows that productivity has increased between $t-1$ and t . If $MPI = 1$, there is no change in productivity, and if $MPI < 1$, productivity has declined. Additionally, as shown in Equation (2), MPI can be decomposed into efficiency change (EC) and technological change (TC) (Färe *et al.*, 1994).

11) This section was written with reference to Coelli *et al.* (1998), Färe *et al.* (1994), Umetsu *et al.* (2003) and Yamamoto *et al.* (2007).

12) In this paper, we assume constant returns to scale for the agricultural production of farm households and estimate the production frontier. This assumption is strongly constrained. Nevertheless, Tsuchiya (1967) has shown that Japan's agriculture in the prewar periods before 1955 exhibited constant returns to scale in rice farming.

13) The constant returns to scale of the production function is measured by data envelopment analysis (DEA), thus such a loss is generally referred to as the DEA inefficient. See Charnes *et al.* (1978) for the measurement method for efficiency using input-oriented DEA.

$$\begin{aligned}
\text{MPI} [t-1, t] &= \frac{Y_2 E / Y_2 A_2}{Y_1 B / Y_1 A_1} \left(\frac{Y_1 B}{Y_1 D} \frac{Y_2 C}{Y_2 E} \right)^{\frac{1}{2}} \\
&= \text{EC} [t-1, t] \text{TC} [t-1, t] \\
&= \frac{Y_2 E / Y_2 A_2}{Y_1 B / Y_1 A_1} \left(\frac{Y_1 B / Y_1 A_1}{Y_1 D / Y_1 A_1} \frac{Y_2 C / Y_2 A_2}{Y_2 E / Y_2 A_2} \right)^{\frac{1}{2}} \quad (2)
\end{aligned}$$

The first term of Equation (2) is EC, and the second term is TC. If $\text{EC} > 1$, this means that from $t-1$ to t , farm households approached the production frontier. Conversely, if $\text{EC} = 1$ or $\text{EC} < 1$, this means that the distance to the production frontier is unchanged or greater. In other words, EC means to what degree there has been catch-up on the intertemporal production frontier. In addition, if $\text{TC} > 1$, this means that the production frontier expanded from $t-1$ to t . That is, it represents a change to an input/output relationship that can produce more products with less inputs. Additionally, if $\text{TC} = 1$ or $\text{TC} < 1$, there is no change in the production frontier, or the production frontier has shrunk. Thus, TC represents the shift in the production frontier. Note that temporary fluctuations of the production frontier can also be interpreted as a spurious technical deterioration due to the temporary deviation of farm households located on the frontier.

2) Malmquist productivity of farm households in prewar Japan

Table 4 shows the input and output variables used for calculating Malmquist productivity. The outputs are rice and silk thread, and the inputs are arable land area, labor, fertilizer, horses, and cows.¹⁴⁾ The balanced panel data of 39 farm households from the IAAS is used, and the period covered is 1924 to 1933. Since

there was no data concerning the weight of fertilizer input in the IAAS, the input weight was calculated by dividing the total fertilizer cost (including self-supplied fertilizer) by the farm gate price of ammonium sulfate per 10 *kan*.¹⁵⁾ We then estimated the amount of fertilizer used for rice farming and sericulture by proportionally dividing the input weight by the area of rice and mulberry fields occupying the total area of arable land. In addition, we estimated the working days of horses and cows by proportionally dividing the area of rice and mulberry fields that occupied the total arable land.¹⁶⁾ In Table 4, for the values in 1930 and 1931, which represents the input amount just before and after the depression respectively, there is no major change in the arable land area, while the area of mulberry fields decreases and that of rice fields increases. Nonetheless, there is no major change in the number of working days. This suggests that the surplus labor in farm households, resulting from the reduction of the mulberry fields due to a sharp fall in the cocoon price and the reduction of silk thread production, was allocated to rice production.

Nevertheless, the amount of fertilizer input increased before and after the depression. While the input amount of purchased fertilizer decreased, the input amount of self-supplied fertilizer increased.¹⁷⁾ This suggests a qualitative change in input fertilizer due to reductions in purchased fertilizer after the depression and substitution with self-supplied fertilizer. The measurement results of Malmquist productivity, TC, and EC, calculated using the above input/output variables, are shown in Figures 3, 4 and 5. Each productivity index shows the cumulative value based on 1924. The cumulative value is the productivity index of the

14) The reasons for using rice and silk thread as the output are threefold. First, many of the surveyed farm households were engaged in rice farming and sericulture. Second, the kinds of crops produced apart from sericulture were diverse. Third, the farm gate price of farm products other than rice and silk thread is unknown, and the amount of production cannot be estimated based on weight.

15) Regarding the farm gate price, some samples were unknown. For these samples, we used the predicted value obtained through linear interpolation.

16) Even if the silk thread production in a specific year was zero, if the mulberry area was positive in the data the mulberry field area was included in the arable land area. This is because we cannot distinguish from the data whether the silk thread production was interrupted in the production process or that the mulberry field was not cultivated. However, if an unused mulberry field is included in the arable land area, we note that the estimates may entail biases because productivity is measured assuming the use of fertilizers and livestock in the mulberry field.

17) This increase in self-supplied fertilizer input might be due to a decrease in purchased fertilizer input due to the expansion of the *Schere*. According to Hayami (1963), the rate of increase in fertilizer input during the agricultural depression (1929–1933) is -2.74% and 3.89% per year for commercial fertilizer and self-supplied fertilizer, respectively. Additionally, commercial fertilizer was substituted by self-supplied fertilizer. From 1883 to 1958, the rate of increase in commercial fertilizer is negative only during the agricultural depression, and this is a remarkable trend that is not observed in other periods. Furthermore, as shown in Table 4, the number of sheets of sericulture egg paper decreased rapidly from 1930 to 1931. This is because the number of the sampled sericulture farm households after the depression declined from 64% (1930) to 51% (1932), which was likely due to exits from sericulture and a decline in silk thread production.

Table 4. Input and output variables used for calculating Malmquist productivity

Year	Input				Output	
	Arable land (<i>tan</i>)	Labor (day)	Fertilizer (<i>kan</i>)	Horse and cow for farming (day)	Rice (<i>koku</i>)	Silk (sheet)
1924	14.9 (13.0, 1.9)	402.6 (360.5, 42.1)	510.0 (284.9, 225.1)	30.4	34.4	7.4
1925	15.5 (13.3, 2.2)	387.7 (337.2, 50.5)	575.6 (336.2, 239.4)	30.1	37.9	8.0
1926	16.2 (13.8, 2.5)	405.8 (345.9, 59.9)	640.2 (368.8, 271.4)	29.6	38.6	9.2
1927	16.3 (13.7, 2.6)	382.2 (323.7, 58.5)	680.1 (381.5, 298.5)	26.6	40.3	9.4
1928	16.3 (13.6, 2.7)	370.8 (306.7, 64.1)	760.6 (412.4, 348.2)	28.1	40.4	9.8
1929	16.6 (13.9, 2.7)	387.6 (324.8, 62.8)	772.4 (443.5, 329.0)	26.6	40.4	9.1
1930	16.5 (13.9, 2.7)	371.8 (310.4, 61.4)	832.2 (495.7, 336.5)	27.4	43.8	8.3
1931	16.4 (14.1, 2.3)	352.2 (293.9, 58.2)	871.7 (459.6, 412.1)	27.5	39.1	6.4
1932	16.3 (14.2, 2.1)	348.2 (287.3, 60.9)	895.9 (479.0, 416.9)	25.6	41.6	6.8
1933	16.1 (14.1, 2.1)	355.4 (287.2, 68.2)	818.8 (433.8, 385.0)	25.4	44.5	7.8

Notes: 1) Arable land represents the sum of paddy rice area and mulberry area. Labor represents the sum of working days of family and hired labor for paddy rice and sericulture. Fertilizer represents the weight of fertilizer, calculated by dividing the total fertilizer cost (including self-supplied fertilizer) by the farm gate price of ammonium sulfate per 10 *kan*. The fertilizer input weight was then multiplied by the proportion of the area of the paddy rice fields and mulberry fields occupying the total cultivated land area. Horses and cows for farming represent the days of use, estimated by using the ratio between the area of paddy rice or mulberry and the total cultivated area.

2) 1 *kan* = 3.75 kg, 1 *koku* = approx. 150 kg.

3) Figures in parentheses for arable land represent the area of paddy rice and mulberry respectively. Figures in parentheses for labor represent the number of days of family labor and hired labor respectively. Figures in parentheses for fertilizer represent the weight of purchased fertilizer and self-supplied fertilizer respectively.

current year multiplied by the productivity index of the previous year.

Figure 3 shows the trend in Malmquist productivity, demonstrating that productivity was on an upward trend throughout the survey period. However, after the depression, productivity declined temporarily in 1931.¹⁸⁾ The reasons for this are as follows: 1) the qualitative deterioration of input factors after the *Schere*; 2) the surplus labor in farm households due to the reduction in sericulture production; and 3) farm

households could not respond to aggregate shocks rapidly or adjust resource allocation smoothly. Additionally, as mentioned in section 2, the farm households surveyed in the *IAAS* are somewhat biased toward medium and large-scale farm households with relatively high levels of agricultural technology. Nevertheless, the fact that these results were obtained suggests that even the middle and large-scale farm households could not avoid declines in productivity after the depression. However, we cannot identify determinants of the de-

18) The decline in Malmquist productivity can also be expressed as a deviation from the trend of the survey period. We examined the degree of deviation from the trend in Malmquist productivity after the depression by regressing Malmquist productivity (cumulative value) on the trend term and the 1931 year dummy. The estimation result was $M = 0.968 (24.89) + 0.042 (6.43) * trend - 0.203 (-3.25) * D_{1931} + \varepsilon$ and the coefficient was statistically significant at the 1% or 5% levels. Note that M is Malmquist productivity (cumulative value), $trend$ is the trend term, D_{1931} is a dummy variable that sets 1931 to 1, ε is the error term, and the value in parentheses indicates the t value. This result indicates that Malmquist productivity was on an upward trend throughout the survey period, and that in the year 1931 after the depression, a rapid decline in productivity occurred, which deviates by about 0.20 from the trend.

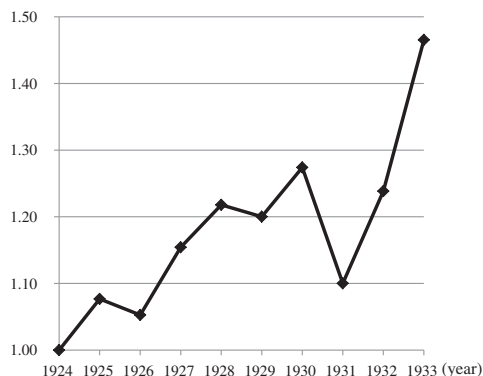


Figure 3. Malmquist productivity (cumulative index), 1924-1933

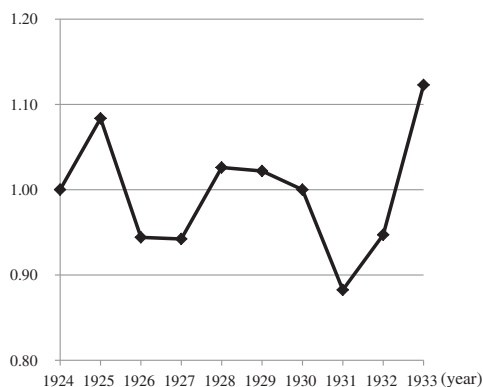


Figure 4. Technological change (cumulative index), 1924-1933

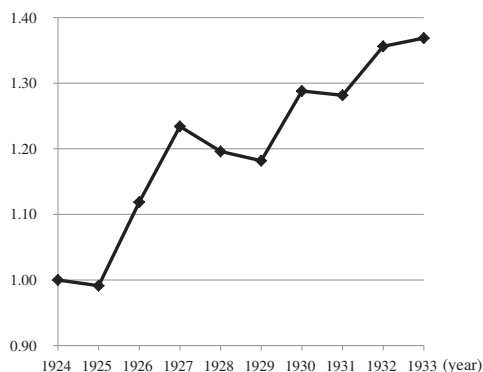


Figure 5. Efficiency change (cumulative index), 1924-1933

cline only from the trend in Malmquist productivity.

Thus, we investigate the dynamics of TC and EC, which decomposed Malmquist productivity. For the trends of TC in Figure 4, we can find that the trend has been around 1, except for the good harvest in 1925, and TC was likely to stagnate in the latter half of the 1920s. This suggests that the production frontier did not shift rapidly during this period and supports the stagnation of agricultural technological progress during the inter-war period. Additionally, Malmquist productivity fell more than 10% from 1930 to 1931. However, it recovered after 1932. This indicates that the production frontier temporarily retreated due to aggregate shocks caused by the depression.

Although the EC shown in Figure 5 was on an upward trend throughout the survey period, EC stagnated temporarily in the latter half of the 1920s and it did not change much immediately after the depression. This indicates that the main factor behind the increase in Malmquist productivity in the latter half of the 1920s was the growth in EC, that is, unskilled farm households located far from the production frontier improved their allocative efficiency and approached the frontier. Nevertheless, it is suggested that the main cause of the Malmquist productivity decline after the depression was a decrease in TC, that is, a temporary shrinkage of the production frontier.

5. Productivity of Farm Households and Aggregate Shocks

Our measurement of Malmquist productivity in the previous section, demonstrated that it decreased temporarily due to technological change after the Showa depression. However, we cannot identify the determinants of Malmquist productivity only through the trend in Malmquist productivity. Therefore, what were the determinants of Malmquist productivity at the farm household level? Also, how farm households were vulnerable to aggregate shocks from the depression and faced a more rapid decline in productivity? In this section, we address these questions through econometric analysis using farm household panel data. First we analyze panel data using the Malmquist productivity indices, TC, and EC, which were measured in the previous section as dependent variables. We then investigate the determinants of these dependent variables. Finally, we examine how aggregate shocks affected the productivity indices.

1) Determinants of the productivity indices of farm households in prewar

Table 5 shows the descriptive statistics of the independent variables used in the analysis.¹⁹⁾ First, we estimated the fixed effect model of panel data using only

Table 5. Descriptive statistics of the independent variables

Variable	Sample	Mean	Standard deviation	Minimum	Maximum
Owner-cultivator dummy	390	0.513	0.500	0.000	1.000
Ratio of rice income	390	0.375	0.171	0.033	0.804
Ratio of sericulture income	390	0.096	0.110	0.000	0.456
Crop diversity	390	0.697	0.105	0.270	0.851
Ratio of leased land (%)	390	14.999	22.597	0.000	81.768
Land/Labor ratio	390	0.023	0.010	0.009	0.153
Ratio of hired labor (%)	390	12.907	16.028	0.000	71.026
Arable land (<i>tan</i>)	390	21.521	8.280	9.620	47.901
Area dummy (Tohoku region)	390	0.205	0.404	0.000	1.000
Area dummy (Kinki region)	390	0.179	0.384	0.000	1.000

Note: Figures are summary statistics of the pooled data (1924–1933). The Herfindahl index was used for crop diversity following Kurosaki (2003). (Crop diversity = $1 - \sum s_{it}^2$, s_{it} : ratio of the area of crop i at year t .)

household characteristics and 1930 and 1931 year dummies as independent variables, and the logarithmic values of Malmquist productivity, TC, and EC, as the dependent variables,²⁰⁾ because Malmquist productivity sharply declined from 1930 to 1931. Note that Malmquist productivity at period t represents the change in productivity between $t-1$ and t , so we used $t-1$ period variables as independent variables to address the potential endogeneity.

Table 6 shows the panel estimation results of the determinants of the productivity indices. The estimation result of Malmquist productivity shows that the coefficients of the rice revenue ratio and the sericulture revenue ratio are negative and statistically significant. This suggests that the productivity of rice farm households and sericulture farm households declined throughout the survey period compared to farm households mainly cultivating other crops such as vegetables and fruit trees. In particular, the absolute value of the coefficient of the sericulture revenue ratio is higher than that of the rice revenue ratio, indicating that the productivity of sericulture farm households was lower than the productivity of rice farm households.

Conversely, regarding the estimation results of TC and EC, the sericulture revenue ratio is negative for TC and the rice revenue ratio is negative for EC, and both are statistically significant. These results indicate that the determinants of productivity change differ between

rice production and sericulture production. For farm households that worked mainly in sericulture, Malmquist productivity decreased due to the decline in technical level via shrinkage of the production frontier. For farm households that worked mainly on rice farming, Malmquist productivity fell due to the decline in the number of farm households that could efficiently allocate inputs in the given production frontier.

Next, for crop diversification, we used the Herfindahl index for the crop diversity index (Kurosaki, 2003). If we consider crop diversification as a means to reduce production risk even at the expense of productivity, how would this coping behavior affect Malmquist productivity during the survey period? Our estimation results reveal that the coefficients of crop diversity are negative and statistically significant for Malmquist productivity and EC, while the coefficient for TC is insignificant. This suggests that the decline in productivity due to the adoption of measures to reduce production risk is due to the decline in the allocative efficiency of inputs.²¹⁾ In addition, the coefficient of the land-labor ratio is negative and statistically significant only for TC. This indicates that the decline in productivity during the survey period is due to the decline in the technical level as a result of the deterioration of land-intensive farm households from the production frontier.

Furthermore, regarding the year dummy to clarify

19) Regarding the owner-cultivator dummy variable presented in Table 5, the ratios of owner-cultivator dummies, owner-cum-tenant dummies, and tenant-cum-owner dummies are 51.3%, 37.4%, and 11.3%, respectively. Additionally, five farm households changed their status during the survey period; two farm households changed from owner-cultivator to owner-cum-tenant, one farm household changed from owner-cum-tenant to owner-cultivator, and two farm households changed from owner-cum-tenant to tenant-cum-owner.

20) According to Simar and Wilson (2007), the productivity index measured by DEA exhibits serial correlation. Therefore, for the panel data analysis, we used the robust standard error clustered by year to address the serial correlation of the error term.

Table 6. Panel estimation results of determinants of productivity indices

Dependent variable Independent variable	Ln (Malmquist productivity)		Ln (technological change)		Ln (efficiency change)	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Owner-cultivator dummy	-0.039	0.103	-0.013	0.035	-0.026	0.102
Ratio of rice income	-0.795 ***	0.228	-0.070	0.229	-0.725 *	0.358
Ratio of sericulture income	-1.106 **	0.442	-1.070 *	0.468	-0.036	0.409
Crop diversity	-0.905 **	0.368	0.418	0.228	-1.323 ***	0.335
Land/Labor ratio	-2.427	1.639	-1.593 ***	0.400	-0.834	1.601
Ratio of hired labor	0.001	0.001	0.001	0.001	0.000	0.001
Ratio of leased land	-0.002	0.001	-0.001	0.002	-0.001	0.002
Arable land	-0.002	0.009	0.005	0.006	-0.006	0.012
1930 year dummy	-0.248 ***	0.023	-0.184 ***	0.038	-0.064 **	0.027
1931 year dummy	0.016	0.023	0.014	0.036	0.001	0.025
Constant	1.199 ***	0.246	-0.186	0.185	1.386 ***	0.263
Observations	351		351		351	
R ²	0.124		0.227		0.053	
Model	Fixed effect		Fixed effect		Fixed effect	

Notes: 1) * Significant at 10%. ** Significant at 5%. *** Significant at 1%.

2) Robust standard errors are clustered by year.

the effects of the depression, the coefficient of the 1930 year dummy is negative and statistically significant for Malmquist productivity, TC, and EC.²¹⁾ However, the 1931 year dummy was insignificant for the three productivity indices. Therefore, the aggregate shock of 1930 caused by the depression led to productivity declines from 1930 to 1931. We found that the productivity decline resulted from temporary declines in both the allocative efficiency of inputs and the level of agricultural technology due to shrinkage of the production frontier. In addition, the owner-cultivator dummy and the size of the area of arable land had an insignificant effect on Malmquist productivity. In other words, there is no productivity gap among owner-cultivator, owner-cum-tenant and tenant-cum-owner, and there is no difference across farm size. Kajii (1986) analyzed *The Rice Production Cost Survey (Teikoku Nokai)*, and clarified that from the late Taisho period to the depression, the owner-cultivator did not necessarily have an advantage in rice yields and labor productivity. He concluded that productivity disparities between the owner-cultivator and tenant farm-

ers were exhausted and the productivity gap due to farm size had not yet been established. Our findings are consistent with these points.

The above findings suggest that the main crop, land allocation, and relative factor endowments of land and labor within farm households were determinants of productivity of farm households during the inter-war period. In addition, the effect of aggregate shocks from the depression, which cannot be explained by household characteristics, was observed in 1930. Aggregate shock caused a decline in productivity which consisted of TC and EC. This raises the questions of how farm households were vulnerable to aggregate shock caused by the depression and how they faced the decline in productivity. In the next section, we examine the factors via aggregate shock on the productivity indices of farm households such as Malmquist productivity.

2) Productivity of farm households and aggregate shocks

To clarify what factors affected the productivity indices via aggregate shock, we examine the causal path of aggregate shock on the productivity indices by in-

21) For example, according to the article "Challenges facing the complication of farm management" (dated June 21, 1931) in the *Chugai Commercial Newspaper*, as farm management practices became more diversified after 1931, four reasons for this behavior were offered: natural conditions, market relations, agricultural organization, and the individual circumstances of the farm households. The author added, "Although diversification is one way of improving farm management, it is not everything, so even in areas where diversification is advantageous, excessive diversification will have adverse effects." The harmful effects of crop diversification were thus pointed out.

22) We also estimated including all of the year dummy variables. The estimation result showed that only the 1930 year dummy was statistically significant, and that it was similar to the result in Table 6.

cluding independent variables as the product terms of the 1930 and 1931 year dummies and household characteristics. We estimated the fixed effect model including the product terms of the year dummies and independent variables in Table 6. In addition, to investigate region-specific shock, we included area dummy variables (Tohoku and Kinki regions), which are representative zone classifications of prewar Japanese agriculture.²³⁾ Estimation results are shown in Table 7.

Table 7 shows two estimation results for Malmquist productivity. One estimation result includes all the product terms and the other removes the insignificant product terms. We also show the estimation results for TC and EC, which Malmquist productivity is decomposed into. The coefficient estimate of Malmquist productivity has been decomposed into the coefficient estimates of TC and EC, and the sum of these two coefficient estimates is equal to the coefficient estimate of Malmquist productivity. We discuss below the interpretation based on the estimation result with the statistically insignificant variables removed. Regarding the variables of household characteristics, we obtained qualitatively similar results in Table 6 with respect to their significance and signs. Thus we only discuss the estimation results for the product terms to focus on the relationship between aggregate shocks and productivity indices.

For the region-specific shock shown in Table 7, both the coefficients of 1930 Tohoku (1930 year dummy*Tohoku region) and 1930 Kinki (1930 year dummy*Kinki region) were negative and statistically significant, and the coefficient of the 1931 Tohoku dummy (1931 year dummy*Tohoku region) was also negative and statistically significant. In addition, the coefficient is -0.246 in 1930 Tohoku and -0.101 in Kinki, indicating that the effect of aggregate shocks on productivity was heavier and more sustained in Tohoku than Kinki. Regarding EC, the Tohoku 1930 dummy is negative and statistically significant, while the coefficient is insignificant for TC. This suggests that the shock specific to Tohoku in 1930 was due to the decline in allocative efficiency. In addition, while the coefficient of 1930 Tohoku was -0.229 for EC, it was -0.417 in 1931. This suggests that the decline in allocative efficiency grew to contribute greatly to the productivity decline due to aggregate shocks. In Tohoku, where the development of commercialized farming was delayed compared to Kinki, the rural labor market,

such as rural manufacturing, was underdeveloped (Nakamura, 1979). This may have led to the inefficiency of labor allocation in farm households in Tohoku region. Thus aggregate shocks in the Tohoku region may have reduced allocative efficiency compared to the Kinki region.

Next, for the crop-specific shocks, the coefficient of the rice revenue ratio is negative and statistically significant, indicating that the aggregate shocks due to the depression led to a decline in the productivity of farm households, especially for rice farming. For 1930, the coefficient of the rice revenue ratio is -1.298 ($= -0.852 + (-0.446)$), which is smaller than the coefficient of the sericulture revenue ratio (-1.115). This suggests that rice farming was more vulnerable to aggregate shocks than sericulture farming. Regarding the crop-specific shock of rice farming on TC and EC, the coefficient for EC (-0.336) is smaller than the coefficient for TC (-0.111), and the coefficient for EC accounts for three-quarters of the coefficient for Malmquist productivity (-0.446). This suggests that much of the decline in productivity in rice farming due to aggregate shocks resulted from a decline in allocative efficiency. Conversely, in 1931, the coefficient of the rice revenue ratio for Malmquist productivity is positive and statistically significant, and the decline in productivity in rice farming could slow and recover from the aggregate shocks. For this recovery, the coefficient for EC is only positive and statistically significant. This suggests that the recovery from the aggregate shocks in rice farming in 1931 can be attributed to the improvement in allocative efficiency.

Furthermore, the coefficient of the sericulture revenue ratio in 1931 for Malmquist productivity is positive and statistically significant. The coefficient related to sericulture revenue ratio is -0.167 ($= -1.155 + 0.988$), and this indicates that the decline in sericulture productivity slowed after the depression. However, this does not mean that sericulture farming recovered from the aggregate shocks. In fact, the cocoon price declined before the depression and also fell dramatically as a result of the depression. Therefore, households whose productivity was relatively low exited sericulture, and those that remained in sericulture had relatively high productivity. Thus the decline in the productivity of sericulture farming might have been alleviated.²⁴⁾ For the estimation results of TC and EC, the coefficient related to the mitigation of the deterioration in produc-

23) Yamada (1934) is one of representative studies on the zone classification of prewar Japanese agriculture in the field of economic history. He proposed "Tohoku region type" and "Kinki region type". Nakamura (1979) added a "sericulture type" to this classification, and examined farmer class decomposition and landowner/tenancy relationships. Note that we did not include a "sericulture type" in the estimation, because the sample size of the sericulture type was small.

Table 7. Aggregate shocks and productivity indices

Dependent variable Independent variable	ln (Malmquist productivity)		ln (Malmquist productivity)		ln (technological change)		ln (efficiency change)	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
<i>Household characteristics</i>								
Owner-cultivator dummy	-0.026	0.117	-0.018	0.107	0.002	0.032	-0.020	0.103
Ratio of rice income	-0.831 **	0.275	-0.852 ***	0.244	-0.131	0.221	-0.721 *	0.359
Ratio of sericulture income	-1.169 **	0.446	-1.155 **	0.453	-1.119 **	0.448	-0.036	0.446
Crop diversity	-1.062 **	0.340	-1.136 ***	0.314	0.479	0.278	-1.615 ***	0.292
Land/Labor ratio	-2.247	1.672	-2.257	1.645	-1.547 ***	0.407	-0.710	1.549
Ratio of hired labor	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001
Ratio of leased land	-0.002	0.002	-0.002	0.002	-0.001	0.002	-0.001	0.002
Arable land	-0.003	0.008	-0.004	0.008	0.005	0.007	-0.008	0.012
<i>Region-specific shocks</i>								
1930 * Tohoku	-0.229 ***	0.064	-0.246 ***	0.071	-0.017	0.032	-0.229 ***	0.068
1931 * Tohoku	-0.299 ***	0.056	-0.308 ***	0.058	0.108 *	0.053	-0.417 ***	0.083
1930 * Kinki	-0.097 **	0.042	-0.101 **	0.036	0.072 ***	0.016	-0.173 ***	0.036
1931 * Kinki	0.072	0.043						
<i>Crop-specific shocks</i>								
1930 * Ratio of rice income	-0.494 ***	0.123	-0.446 ***	0.127	-0.111 **	0.037	-0.336 ***	0.111
1931 * Ratio of rice income	0.392 ***	0.109	0.396 ***	0.111	-0.100	0.078	0.496 ***	0.072
1930 * Ratio of sericulture income	-0.061	0.292						
1931 * Ratio of sericulture income	1.123 ***	0.238	0.988 ***	0.212	0.719 ***	0.142	0.269	0.235
<i>Household-specific shocks</i>								
1930 * Owner-cultivator dummy	0.026	0.072						
1931 * Owner-cultivator dummy	0.073	0.069						
1930 * Crop diversity	-0.467 ***	0.050	-0.453 ***	0.049	-0.394 ***	0.057	-0.059	0.056
1931 * Crop diversity	-0.102	0.063						
1930 * Land/Labor ratio	0.942	3.596						
1931 * Land/Labor ratio	-20.841 ***	4.015	-19.382 ***	2.202	-6.104 **	2.082	-13.278 ***	1.723
1930 * Ratio of hired labor	-0.001	0.001						
1931 * Ratio of hired labor	0.003 *	0.001	0.004 **	0.002	0.000	0.001	0.004 **	0.001
1930 * Ratio of leased land	0.004 ***	0.001	0.003 ***	0.001	0.002 ***	0.000	0.002	0.001
1931 * Ratio of leased land	0.001	0.001						
1930 * Arable land	0.011 **	0.004	0.011 ***	0.003	0.004 ***	0.001	0.007 *	0.003
1931 * Arable land	0.013 ***	0.004	0.011 ***	0.003	0.005 **	0.002	0.006 *	0.003
Constant	1.352 ***	0.227	1.410 ***	0.202	-0.215	0.225	1.625 ***	0.247
Observations	351		351		351		351	
R ²	0.165		0.164		0.290		0.090	
Model	Fixed effect		Fixed effect		Fixed effect		Fixed effect	

Note: See Table 6.

tivity is positive and significant only for TC. This suggests that the mitigation of the decline in productivity was due to the expansion of the production frontier of the sericulture households and more specifically, the recovery of the technical level of sericulture. This confirms the exit of unskilled sericulture households. As

described above, regarding the 1931 dummy which was insignificant in Table 6, we could find shocks specific to Tohoku region and sericulture households, decomposing the aggregate shocks into several shocks.

Next, for household-specific shocks, the coefficient of crop diversity in 1930 for Malmquist productivity is

24) The proportion of households with sericulture revenue ratio of 20% or more were 18% of the whole sample in 1929, but fell to 8% in 1931. In addition, the proportion of sericulture management also declined from 64% (1930) to 51% (1932) of the whole sample, which shows the evidence of exits from sericulture due to the depression.

negative and statistically significant. Although crop diversification was adopted as a means of reducing production risk and smoothing the labor force, it could not act as a means of risk aversion if all agricultural product prices decrease due to aggregate shock. As Ouchi (1960) noted, crop diversification could lead to labor intensification.²⁵⁾ In addition, the reduction of current inputs to cope with the depression may also have reduced productivity (Fujie and Senda, 2011). Also, regarding the decline in productivity caused by crop diversification, the coefficient of crop diversification is negative and statistically significant only for TC. In other words, crop diversification aimed at risk aversion led to reduce productivity via a temporary decline in the technical level due to the shrinkage of the production frontier.

Furthermore, the coefficients of the land-labor ratio and hired labor ratio in 1931 for Malmquist productivity are negative and positive, respectively, and statistically significant. This indicates that land-intensive farm households are more vulnerable to aggregate shocks, while households hiring labor are relatively robust. The coefficients of the land-labor ratio for TC and EC were negative and statistically significant. This indicates that the reduction in the Malmquist productivity in land-intensive management can be attributed to a drop in technical level and allocative efficiency. In addition, the coefficients of the land-labor ratio in 1931 (1931 year dummy*land/labor ratio) for TC and EC are -6.104 and -13.278, respectively, and the coefficient for EC is smaller. This indicates that the decline in productivity regarding land-intensive management can be attributed to the decline in allocative efficiency rather than to the reduction in the technical level. However, the coefficient of the hired labor ratio in 1931 for TC and EC is positive and statistically significant only for EC. This implies that there was robustness against aggregate shock among households hiring labor.

Finally, we examine the coefficients related to the leased area ratio and the arable land area. The coefficient of the leased area ratio in 1930 for Malmquist productivity is positive and statistically significant. This suggests that tenant farmers were more robust against aggregate shocks than were owner farmers. The estimation results of the leased area ratio for TC and EC is positive and statistically significant only for TC. This indicates that the robustness of tenant farmers was caused by their control of the decline in technical levels. Second, the coefficients of arable land for

Malmquist productivity in 1930 and 1931 are both positive and statistically significant. The coefficients of arable land for TC and EC in 1930 and 1931 are also positive and statistically significant. This indicates that medium/large-scale farm households had an advantage over small farm households in TC and EC, and therefore medium/large-scale farm households were robust against aggregate shocks. These results for the hired labor ratio, leased area ratio, and arable land suggest that medium/large-scale farm households, which were able to enlarge their farms by leasing land and employing labor, were robust against aggregate shocks. Kajii (1986) noted that the productivity of medium/large-scale farm households had a further advantage over small-scale farm households after the depression. Our results suggest that the advantage of large-scale farm households after the depression was based on the robustness of medium/large-scale farm against aggregate shocks. Moreover, the difference in terms of farm size regarding the vulnerability to aggregate shocks might have led to the downfall of small farm households and the dominance of medium/large-scale farm households, which later triggered changes in the structure of Japan's agriculture.

Overall, we found that farm households in Tohoku region were more vulnerable than those in Kinki region against aggregate shocks from the Showa depression and that large farm households were robust against these shocks. In addition, the aggregate shocks due to the depression led to a decline in the productivity of small-scale rice farm households, sericulture management, and land-intensive farm households in prewar Japan. Furthermore, crop diversification as a means of mitigating production risk was not effective and the majority of farm households inevitably experienced declining productivity. The vulnerability of productivity against aggregate shocks reduced technical levels due to shrinking of the production frontier or declines in allocative efficiency, and the causal path of the decline in productivity varied depending on these various factors.

6. Conclusion

Man-made disasters and natural disasters have characteristics as aggregate shocks that make mutual insurance and insurance difficult in local areas. In this paper, we focused on the Showa depression as an example of aggregate shocks and examined the effects of the Showa depression on the productivity of farm house-

25) Based on the trend in the production index that shows the remarkable growth of vegetables, fruit trees, livestock, etc., which was triggered by the depression, Ouchi (1960) notes both that the growth of these crops is a form of diversification rather than commercialized farming and that it is a form of labor intensification.

holds. We used farm household panel data that includes the Showa depression, and measured the Malmquist productivity of each farm household and decomposed the Malmquist productivity into technical change and efficiency change. We then investigated the trends of these indices. We also estimated a fixed effect model to clarify the vulnerability of farm households against aggregate shock.

Our main findings are as follows. First, in 1930 to 1931 after the depression, Malmquist productivity declined sharply; this was not seen in other periods. This decline in productivity was due to a temporary drop in the technical level due to the shrinkage of the production frontier and a decline in the allocative efficiency of inputs.

Second, there are regional variations for the vulnerability to aggregate shocks caused by the Showa depression, and we found that medium/large-scale farm households were robust against aggregate shock. This suggested that the differences in vulnerability among farm sizes could have triggered changes in Japan's agricultural structure after the depression.

Finally, we describe the remaining issues. As mentioned above, in the *Imperial Agricultural Association Survey* used in this paper, the farm size of the farm households surveyed is biased toward the middle/large-scale; therefore, we need to note this bias in our results. Additionally, the decomposition of Malmquist productivity from Färe *et al.* (1994) used in this paper assumes constant returns to scale. Therefore, if the production technology of Japanese agriculture in the prewar does not satisfy this assumption, Malmquist productivity may be improperly decomposed. For example, Ray and Desli (1997) propose a decomposition method that does not only assume variable returns to scale, and decomposed elements can be measured according to the assumptions of this production technology. Furthermore, as much of the previous literature indicated, the outliers in DEA affect the measurement results of Malmquist productivity. In the future, it will be necessary to consider such new decomposition methods. In addition, we can also measure total factor productivity in the rice farming sector using the *Imperial Agricultural Association Survey*. Thus, we can understand other aspects of the prewar farm economy through the application of a stochastic frontier model or the measurement of total factor productivity. These remain as issues to be addressed.

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References

- Arimoto, Y. (2012) Participatory Rural Development in 1930s Japan: The Economic Rehabilita-
tion Movement, *Developing Economies* 50 (2):
170–192.
- Arimoto, Y. and Y. Sakane (2008) A Prefecture-
level Panel Data Analysis of Tenancy Disputes:
Labor Market and Restructuring of the Agricul-
tural Sector in Japan, 1915–1929, *Socio-
Economic History* 73 (5): 65–82 (in Japanese).
- Arimoto, Y., T. Fujie and T. Senda (2013) Farmers'
Debt in 1930s Japan, *Economic Review* 64 (1):
13–29 (in Japanese).
- Barrett, C. B., S. M. Sherlund and A. A. Adesina
(2006) Macroeconomic Shocks, Human Capital
and Productive Efficiency: Evidence from West
African Rice Farmers, *Journal of African Econo-
mies* 15 (3): 343–372.
- Caves, D. W., L. R. Christensen and W. E. Diewert
(1982) The Economic Theory of Index Numbers
and the Measurement of Input, Output, and Pro-
ductivity, *Econometrica* 50 (6): 1393–1414.
- Charnes, W., W. Cooper and E. Rhodes (1978)
Measuring the Efficiency of Decision Making
Units, *European Journal of Operational Research*
2: 429–444.
- Coelli, T., D. S. P. Rao and G. E. Battese (1998) *An
Introduction to Efficiency and Productivity Analy-
sis*, Kluwer Academic Publishers.
- Dercon, S. (2005) *Insurance Against Poverty*, Ox-
ford University Press.
- Fallon, P. R. and R. E. B. Lucas (2002) The Impact
of Financial Crises on Labor Market, Household
Incomes, and Poverty: A Review of Evidence,
World Bank Research Observer 17 (1): 21–45.
- Färe, R., S. Grosskopf, M. Norris and Z. Zhang
(1994) Productivity Growth, Technical Progress,
and Efficiency Change in Industrialized Coun-
tries, *American Economic Review* 84 (1): 66–83.
- Fujie, T. and T. Senda (2011) How do Farm House-
holds Cope with Aggregate Shocks? Evidence
from the Great Depression in Prewar Japan, *Jour-
nal of Rural Economics* 83 (1): 15–27 (in Japa-
nese).
- Hayami, Y. (1963) An Estimation of Fertilizer Use:
1883–1941, 1951–1959, *Journal of Agricultural*

- Economy* 17(1): 247-325 (in Japanese).
- Hayami, Y. (1973) *Nihon Nogyo no Seicho Katei* (*The Growth Process of Japanese Agriculture*), Sobun-sha (in Japanese).
- Hayashi, Y. (2003) Sekai Dai Kyoko kara Senji Taisei ye (Transition from the Great Depression to the Wartime Regime), in S. Teruoka, ed., *Nihon Nogyo no 150 Nen: 1850-2000* (150 Years of Japanese Agriculture: 1850-2000), Yuhikaku, 97-121 (in Japanese).
- Inaba, T., ed. (1953) *Fukkokuban Noka Keizai Chosa Hokoku: Chosa Hoho no Hensen to Ruinen Seiseki* (Reprint Edition of the Survey Report on Farm Economy: Transition of the Survey Method and Results during the Whole Survey Period), Nogyo-Sogo-Kenkyu-Kanko-Kai (in Japanese).
- Inomata, T. (1934) *Tosa Hokoku Kyubo no Nosen* (Non-Fiction: Impoverishment in Villages), Iwanami-Shoten (in Japanese).
- Kajii, I. (1986) Nogyo Seisanryoku no Kosei to Seisanryoku Kakusa no Keisei (The Composition of Agricultural Productivity and the Formation of Disparity in Agricultural Productivity), *Nogyo Seisanryoku no Tenkai Kozo* (*The Development Process of Agricultural Productivity*), Tsukuba Shobo, 15-120 (in Japanese).
- Kang, S. J. and Y. Sawada (2009) Did Public Transfers Crowd Out Private Transfers in Korea During the Financial Crisis? *Journal of Development Studies* 45(2): 276-294.
- Kayo, N., ed. (1977) *Kaitei Nihon Nogyo Kiso Tokei* (Revised Version of Basic Statistics on Japan's Agriculture), Norin-Tokei-Kyokai (in Japanese).
- Kurihara, H. (1974) *Nihon Nogyo no Kiso Kozo* (*The Fundamental Structure of Japanese Agriculture*), Azekura-Shobo (in Japanese).
- Kusadokoro, M. (2012) Koshu-Yochiku Fukugo Keiei no Seisan Gijutsu no Keisoku: Senzenki Noka Keizai Chosa no Hensen to Keiryō Bunseki (Measurement of Production Technology of Crop Farming and Sericulture: Transition of the Surveys of Farm Household Economy and Econometric Analysis), in S. Inamoto, ed., *Nogyo Keiei Hatten no Kaikeigaku* (*Accounting in Agricultural Development*), Showa-Do, 227-248 (in Japanese).
- Kusadokoro, M., T. Maru and M. Takashima (2012) Asset Accumulation in Rural Households during the Post-Showa Depression Reconstruction: A Panel Data Analysis, *PRIMCED Discussion Paper Series*, No.23 (in Japanese).
- Kurosaki, T. (2003) Specialization and Diversification in Agricultural Transformation: The Case of West Punjab, 1903-92, *American Journal of Agricultural Economics* 85(2): 372-386.
- Kurosaki, T. (2009) *The Economic Analysis of Poverty and Vulnerability*, Keiso-Shobo (in Japanese).
- Kurosaki, T. (2011) Vulnerability of Households to Village-Level Aggregate Shocks: Evidence from Natural Disasters in Pakistan, *Economic Review* 62(2): 153-165 (in Japanese).
- Malmquist, S. (1953) Index Numbers and Indifference Surfaces, *Trabajos de Estadística* 4: 209-242.
- McKenzie, D. J. (2003) How do Households Cope with Aggregate Shocks? Evidence from the Mexican Peso Crisis, *World Development* 31 (7): 1179-1199.
- McKenzie, D. J. (2004) Aggregate Shocks and Urban Labor Market Responses: Evidence from Argentina's Financial Crisis, *Economic Development and Cultural Change* 53: 719-758.
- Minami, R. (2002) *Nihon no Keizai Hatten* (*Economic Development of Japan*, 3rd ed.), Toyo-Keizai-Shimpo-Sha (in Japanese).
- Nakamura, M. (1979) *Kindai Nihon Jinushisei-Shi Kenkyu* (*Study on the History of the Landlord System in Modern Japan*), University of Tokyo Press (in Japanese).
- Ohkawa, K., M. Shinohara and M. Umemura, eds. (1966) *Choki Keizai Tokei* (*The Long-Term Economic Statistics*), Toyo-Keizai-Shimpo-Sha (in Japanese).
- Ouchi, T. (1960) *Nogyo-Shi* (*Agricultural History*), Toyo-Keizai-Shimpo-Sha (in Japanese).
- Ozeki, M. and M. Sato (2008) From Agricultural Bookkeeping to Household Analysis: The Formation of the Household Analysis Method and the Role of the Kyoto School in that Process, *Economic Review* 59(1): 59-73 (in Japanese).
- Ravallion, M. and M. Lokshin (2007) Lasting Impacts of Indonesia's Financial Crisis, *Economic Development and Cultural Change* 56: 27-56.
- Ray, S. C. and E. Desli (1997) Productivity Growth, Technical Progress, and Efficiency Changes in Industrialized Countries: Comment, *American Economic Review* 87: 1033-1039.
- Saito, O. (2009) The Farm Household and Intra-family Work Patterns -An Analysis of Micro-data for 17 Farms in the Interwar Period-, *Economic Review* 60(2): 126-139 (in Japanese).
- Sakane, Y. (2010) Kindai (Modern Agriculture), in S. Kimura, ed., *Nihon Nogyo-Shi* (*Japan's Agricultural History*), Yoshikawa-Kobun-Kan, 256-

- 336 (in Japanese).
- Sakurai, T. (2006) Civil War Shock, Poverty, and Soil Degradation: Evidence from Rural Household Data in Burkina Faso, *Journal of Rural Economics* 78(1): 34–49 (in Japanese).
- Sakurai, T., A. Nasuda, A. Kizuki, K. Miura, T. Yamauchi and H. Kanno (2011) Vulnerability and Resilience of Households: The Case of Zambia, *Economic Review* 62(2): 166–187 (in Japanese).
- Sawada, Y. (2007) The Impact of Natural and Man-made Disasters on Household Welfare, *Agricultural Economics* 37(s1): 59–73.
- Sawada, Y. and S. Shimizutani (2008) How do People Cope with Natural Disasters? Evidence from the Great Hanshin-Awaji (Kobe) Earthquake in 1995, *Journal of Money, Credit and Banking* 40: 463–488.
- Sawada, Y. (2010) Shizen Saigai, Jinteki Saigai to Kakei Kodo (Natural and Manmade Disasters and Household Behavior), in S. Ikeda, M. Ogaki, A. Shibata, Y. Maeda and R. Miyao, eds., *Gendai Keizaigaku no Choryu 2010 (Trends in Contemporary Economics 2010)*, Toyo-Keizai-Shimpo-Sha, 153–182 (in Japanese).
- Sawada, Y., T. Shoji and S. Sanga (2011) Is Credit Access Effective against Damages Caused by a Natural Disaster? -The Case of Tsunami Victims in Southern India-, *Economic Review* 62(2): 129–140 (in Japanese).
- Senda, T. and M. Kusadokoro (2009) Senzenki Noka Keizai Chosa no Hyohon Renzokusei to Noka Keizai Kozo: Dai 3 ki kara Dai 4 ki ni okeru Kaisei no Eikyo to Teikoku Nokai Keiei Chosa tonon Hikaku ni Chakumokushite (Continuity of Samples and Structure of Farm Household Economy on the Surveys of Farm Household Economy in Prewar Japan), *Tokei Shiryo Series* 63: 83–122 (in Japanese).
- Shoji, M. (2008) How do the Poor Cope with Hardships when Mutual Assistance is Unavailable? *Economics Bulletin* 15(13): 1–17.
- Simar, L. and P. W. Wilson (2007) Estimation and Inference in Two-Stage, Semi-Parametric Models of Production Processes, *Journal of Econometrics* 136: 31–64.
- Smith, J. P., D. Thomas, E. Frankenberg, K. Beegle and G. Teruel (2002) Wages, Employment and Economic Shocks: Evidence from Indonesia, *Journal of Population Economics* 15: 161–193.
- Tama, S. (1986) Association in the Inter-War Period: 1920–40, *The Review of Agricultural Economics Hokkaido University* 42: 181–206 (in Japanese).
- Tsuchiya, K. (1967) Econometric Analysis of Japan's Agriculture: Its Perspectives, *The Economic Studies Quarterly* 17(3): 50–64 (in Japanese).
- Umemura, M., S. Yamada, Y. Hayami, N. Takamatsu and M. Kumazaki (1966) Noringyo (Agriculture and Forestry), in K. Ohkawa, M. Shinohara and M. Umemura, eds., *Choki Keizai Tokei (The Long-Term Economic Statistics)* 9, Toyo-Keizai-Shimpo-Sha (in Japanese).
- Umetsu, C., T. Lekprichakul and U. Chakravorty (2003) Efficiency and Technical Change in the Philippine Rice Sector: A Malmquist Total Factor Productivity Analysis, *American Journal of Agricultural Economics* 85(4): 943–963.
- Yamada, M. (1934) *Nihon Shihon Shugi Bunseki: Nihon Shihon Shugi ni okeru Saiseisan Katei Haaku (The Analysis of Japan's Capitalism: Understanding the Process of Reproduction in Japan's Capitalism)*, Iwanami-Shoten (in Japanese).
- Yamada, S. (1963) Nogyo ni okeru Tonyu Sanshutu no Choki Hendo (The Long-Term Dynamics of Input-Output in Agriculture), in K. Ohkawa, ed., *Nihon Nogyo no Seicho Bunseki (The Analysis of Growth in Japan's Agriculture)*, Taimei-Do, 85–98 (in Japanese).
- Yamamoto, Y., K. Kondo and J. Sasaki (2007) Will the Growth Rate of Japan's Rice Productivity Decline to Zero Percent in the Future? A Nonparametric Analysis on Total Factor Productivity, Technical Change and Catching-up Effect, *Journal of Rural Economics* 79(3): 154–165 (in Japanese).
- Zhengfei, G. and A. O. Lansink (2006) The Source of Productivity Growth in Dutch Agriculture: A Perspective from Finance, *American Journal of Agricultural Economics* 88(3): 644–656.

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Appendix 1. Location of surveyed farm households

Sample number	Prefecture	Village name	Sample number	Prefecture	Village name	Sample number	Prefecture	Village name
1	Iwate	Ohfuke	14	Tokyo	Kasumi	27	Nara	Taisho
2	Iwate	Saraki	15	Toyama	Ohfuse	28	Wakayama	Ogura
3	Akita	Higashidate	16	Ishikawa	Itazu	29	Wakayama	Fujinami
4	Yamagata	Chugun	17	Fukui	Okabo	30	Tottori	Koyama
5	Yamagata	Motosawa	18	Gifu	Ohta	31	Shimane	Hisagi
6	Fukushima	Shojo	19	Gifu	Uguisu	32	Okayama	Souyou
7	Fukushima	Izumi	20	Aichi	Iwazu	33	Yamaguchi	Higashikiwa
8	Fukushima	Toyoda	21	Mie	Ugawara	34	Tokushima	Kawauchi
9	Ibaraki	Morito	22	Mie	Ouka	35	Tokushima	Isawa
10	Tochigi	Mizushiro	23	Kyoto	Tomimoto	36	Kagawa	Hashioka
11	Saitama	Irima	24	Osaka	Nishitouki	37	Ehime	Yamada
12	Chiba	Tomisato	25	Hyogo	Sonoda	38	Saga	Kitataku
13	Chiba	Kyowa	26	Nara	Masuga	39	Nagasaki	Nakazato

Appendix 2. Comparison of used samples and attrition samples

Year		Used samples	Attrition samples	Year		Used samples	Attrition samples
1924	Ratio of owner-cultivator (%)	53.9	43.8	1929	Ratio of owner-cultivator (%)	48.7	36.5
	Ratio of rice income (%)	42.6	45.9		Ratio of rice income (%)	35.1	37.5
	Ratio of sericulture income (%)	8.9	8.7		Ratio of sericulture income (%)	11.2	12.1
	Arable land (<i>tan</i>)	20.3	30.8		Arable land (<i>tan</i>)	21.8	31.7
	Location (East Japan) (%)	56.4	51.6		Location (East Japan) (%)	56.4	52.0
1925	Ratio of owner-cultivator (%)	53.9	42.2	1930	Ratio of owner-cultivator (%)	51.3	33.3
	Ratio of rice income (%)	39.5	42.9		Ratio of rice income (%)	34.8	37.6
	Ratio of sericulture income (%)	11.7	11.7		Ratio of sericulture income (%)	8.1	8.8
	Arable land (<i>tan</i>)	20.5	31.5		Arable land (<i>tan</i>)	21.8	34.2
	Location (East Japan) (%)	56.4	51.6		Location (East Japan) (%)	56.4	45.7
1926	Ratio of owner-cultivator (%)	51.3	45.3	1931	Ratio of owner-cultivator (%)	51.3	42.9
	Ratio of rice income (%)	38.5	42.3		Ratio of rice income (%)	35.3	35.0
	Ratio of sericulture income (%)	11.0	10.5		Ratio of sericulture income (%)	8.0	7.9
	Arable land (<i>tan</i>)	21.4	32.4		Arable land (<i>tan</i>)	21.9	31.7
	Location (East Japan) (%)	56.4	51.6		Location (East Japan) (%)	56.4	48.2
1927	Ratio of owner-cultivator (%)	51.3	46.0	1932	Ratio of owner-cultivator (%)	51.3	46.7
	Ratio of rice income (%)	39.1	42.7		Ratio of rice income (%)	38.3	40.2
	Ratio of sericulture income (%)	9.9	8.7		Ratio of sericulture income (%)	7.5	11.4
	Arable land (<i>tan</i>)	21.4	32.4		Arable land (<i>tan</i>)	22.0	32.1
	Location (East Japan) (%)	56.4	52.5		Location (East Japan) (%)	56.4	40.0
1928	Ratio of owner-cultivator (%)	48.7	43.8				
	Ratio of rice income (%)	35.7	39.1				
	Ratio of sericulture income (%)	10.8	11.0				
	Arable land (<i>tan</i>)	21.4	32.4				
	Location (East Japan) (%)	56.4	51.6				

Notes: 1) Figures for four samples which were not used for this analysis are excluded.

2) The figures for 1933 are omitted because the attrition sample was one.