Tillers of Prosperity: Land Ownership, Reallocation, and Structural Transformation*

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Abstract

This paper analyzes the role of land ownership in factor reallocation and structural transformation. Using a novel dataset, I show that the massive land reform enforced by the Allies after World War II, which redistributed the ownership of farmlands from landlords to tenants, led farmers to use more low-cost agricultural technologies when they became available and to rely less on family labor for production, resulting in an increase in the outmigration of the young population from rural to urban areas. A quantitative exercise using a two-sector neoclassical growth model indicates that the impact of the factor reallocation was considerable.

Keywords: Land ownership, property rights, agricultural mechanization, reallocation of capital and labor, structural transformation, micro-macro development

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It is not paying no rent that makes the peasant proprietor industrious; it is that the land is his own.

- John Stuart Mill

1 Introduction

Secure property rights are often regarded as an important precondition for economic development (North, 1981; de Soto, 2000; Sokoloff and Engerman, 2000; Acemoglu et al., 2001, 2002; Besley and Persson, 2011). A significant number of microstudies examining the effect of property rights, and especially the effects of property-right security on agricultural development, are supportive of these arguments (Besley, 1995; Banerjee et al., 2002; Jakoby et al., 2002; Hornbeck, 2010).

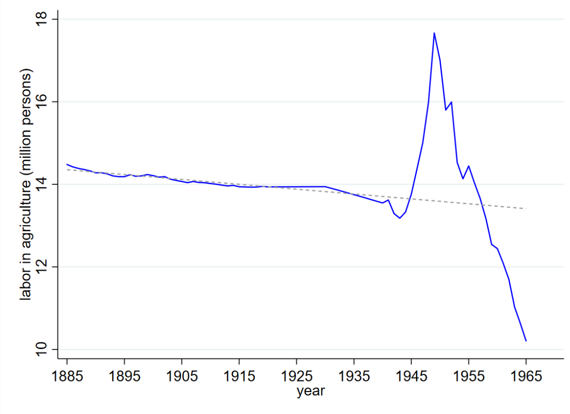
However, the original arguments of property rights concerned not only security but also ownership.[1] In societies where secure property rights already exist, owning land rather than renting it has a different impact on an individual's investment decisions, since the land could be used as collateral, sold, or rented at will, if legally permitted. The existence of a hierarchical structure based on land ownership in the local community may also influence such decisions. In contrast to the studies examining the effect of the security of property rights, however, research on the ownership of property rights has received much less attention. Further, there remains a paucity of studies examining the relationship between property rights (security and ownership) and structural transformation. This paper aims to fill the gaps.

In addition to property rights, the diffusion of advanced technologies in agriculture is deemed to be an important factor in economic development.[2] To give an example, Figure 1 shows the change in the use of labor and capital across sectors in Japan between 1885 and 1965. On one hand, Figure 1 (a) shows the common pattern observed in many countries during structural transformation (Fisher, 1939; Clark, 1957; Herrendorf et al., 2014): agricultural employment decreased over time, especially when the economy grew rapidly.[3] By contrast, Figure 1 (c) illustrates a perhaps less-known pattern during structural transformation: capital, including advanced technologies such as machines, increased in agriculture. The figures clearly show that when the economy grew rapidly and structural transformation became a salient phenomenon, these production factors appeared to be "shuffled" in the economy in the sense that more labor was hired in manufacturing and services, corresponding to the view of the Lewis model (Lewis, 1954), whereas more capital, which was presumably produced in the non-agricultural sector,

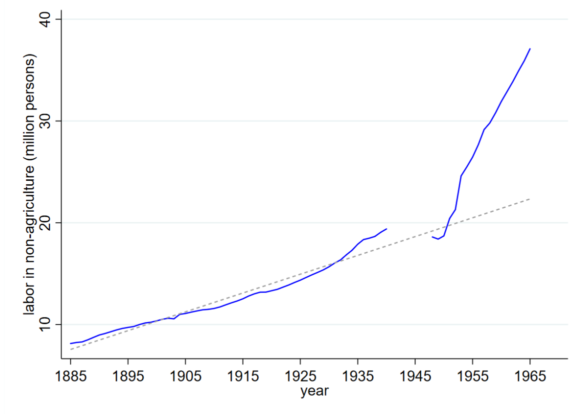
[1] For example, Arthur Young wrote: "Give a man the secure possession of a bleak rock, and he will turn it into a garden; give him a nine years' lease of a garden, and he will convert it into a desert" in *Travels in France* (1792). Quoting Young several times in *The Condition of Ireland* (1846), John Stuart Mill advocated the redistribution of the ownership of unused and uncultivated land from the Anglo-Irish landlords of large estates to Irish peasants (Maurer, 2012).

[2] For example, a technological revolution in agriculture was one of the fundamental conditions for sustained industrialization of the British economy (Rostow, 1959). Gollin et al. (2002) also show the importance of high agricultural productivity for industrialization in the United Kingdom.

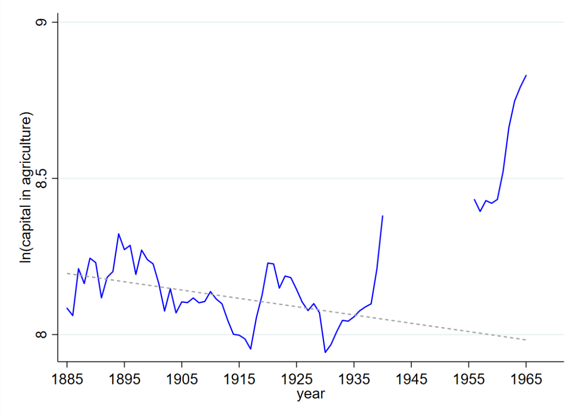
[3] The temporal increases in agricultural employment in the late 1940s were due to the end of World War II.



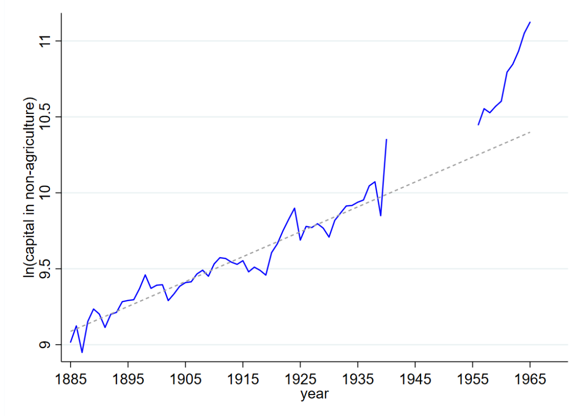
(a) Employment in agriculture



(b) Employment in non-agriculture



(c) Capital in agriculture



(d) Capital in non-agriculture

Notes: Capital in both sectors is in real terms (1934-1936 prices, in units of non-agriculture). Dashed lines in gray are prewar linear trends (1885-1939). I take the natural logarithm for capital in (c) and (d).

Figure 1: Capital and Labor, 1885-1965

was used in agriculture.[4]

Today, developing countries still have a high share of employment in agriculture, and such allocation is often associated with low productivity in that sector (Caselli, 2005; Restuccia et al., 2008; Lagakos and Waugh, 2013; Gollin et al., 2014). At the same time, the adoption rates of advanced agricultural technologies are typically low in these countries, especially in Africa (Pingali, 2007).[5] The limited use of capital in agriculture may also be related with low productivity in that sector (Adamopoulos et al., 2021).

How are land ownership and advanced technologies in agriculture related in the context of structural transformation? This paper answers this question by exploiting two natural experiments. The first experiment was the massive land reform imposed by the Allies in the late

[4] On the other hand, both factors in the non-agricultural sector increased over time, but the slope became steeper in later years ((b), (d)).

[5] To explain the low take-up rates, previous studies have uncovered barriers to technology adoption in agriculture. Such barriers include profitability (Griliches, 1957), imperfect information and learning (Foster and Rosenzweig, 1995; Conley and Udry, 2010; Hanna et al., 2014), low returns (Suri, 2011), time inconsistency (Duflo et al., 2011), and quality of agricultural inputs (Bold et al., 2017). See Foster and Rosenzweig (2010) for a review of the literature. Suri and Udry (2022) also discuss potential constraints for adopting agricultural technology in Africa.

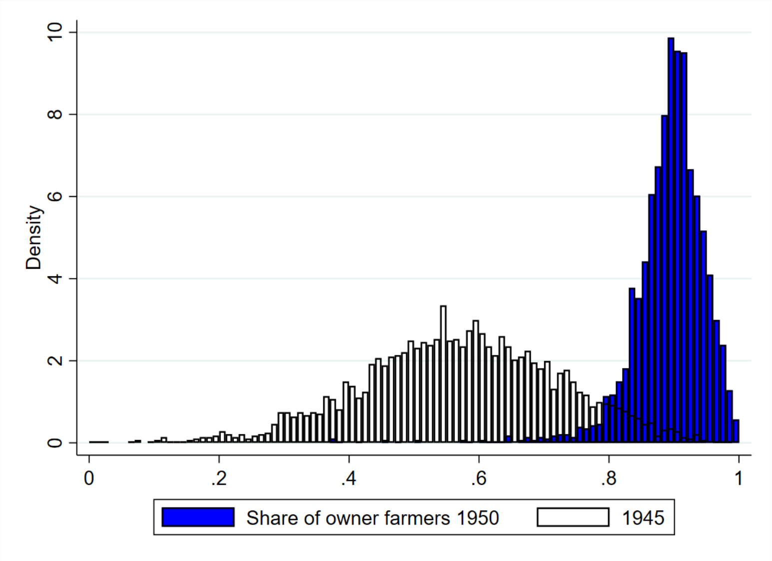


Figure 2: Owner share before and after land reform

1940s, which redistributed the ownership of 2 million hectares of farmlands from landlords to tenant farmers, making many tenant farmers the owners of farmlands (Figure 2). The second experiment was the availability of low-cost agricultural technologies that arose in the late 1950s after the introduction of such technologies from the United States. The first experiment is used as the source of the cross-sectional variation and the second experiment as the source of the time variation in the empirical analysis.

To proceed to the empirical analysis, I construct a unique panel dataset of municipalities using various paper-based sources. Creating such a detailed historical dataset is challenging at first for several reasons, but particularly due to the data availability. For example, many official statistics are archived at an aggregated level such as by prefecture.[6] I thus collect paper-based data at a more disaggregated level and digitize them. Then, using difference-in-differences strategies, I examine the effect of land ownership on the adoption of agricultural technologies and on labor reallocation, when the low-cost technologies become available. Further, the effects on other outcomes such as agricultural income and human capital accumulation are also studied.

I find that, when the new low-cost agricultural technologies became available, land ownership increased their adoption. In addition, land ownership decreased the share of young people in the population, or increased the outmigration of young people. The results still hold under various robustness checks including an alternative estimation strategy in which the variation of adjacent municipalities along either side of the prefectural boundary is used. The economic significance is also considerable: one standard deviation increase in the land ownership increases the adoption by 1.06 standard deviation (a 792% increase from the control mean) and decreases the share of young people by 0.65 standard deviation (a 7% decrease from the control mean). The main migrants tended to be second and younger sons, and daughters, possibly reflecting the primogeniture culture of the country, but the eldest sons also migrated if they were young. Rather than continuing their education, they began working in non-agricultural

[6] A municipality and a prefecture are similar to a county and a state in the United States, respectively.

sectors. Moreover, I also find evidence that land ownership increased agricultural income.

Next, I examine heterogeneous effects in terms of farm sizes. This analysis echoes recent discussion on the relationship between farm size and productivity in agriculture (e.g., Foster and Rosenzweig, 2011, 2022; Adamopoulos and Restuccia, 2014). I find evidence suggesting that the effects are larger for larger farmers, more or less linearly, although such differences are not statistically significant. I discuss possible explanations for this finding in the paper.

To investigate the mechanism underlying the above findings, I study the interaction between land ownership and credit access. To do so, I use the membership of agricultural cooperatives, which were the main suppliers of loans for farmers at the time, as the source of variation. This relates to a phenomenon known as the *de Soto* effect (de Soto, 2000; Besley et al., 2012): owner farmers might have been able to use their farmlands as collateral for taking loans. I find supporting evidence that the effects of land ownership are larger in areas where a higher share of the agricultural population belongs to the agricultural cooperatives.

To evaluate the overall effect of factor reallocation, I simulate a two-sector neoclassical growth model. First, I compute wedges in the prewar period separately for the consumption component (based on the consumer's optimization problem), the production component (based on the producer's optimization problem), and the mobility component (based on market clearing conditions). I find that the consumption and mobility components are negligible, whereas the production component is relatively large, implying that the production side seems to be the driver of the prewar misallocation in the country. In particular, I find that the capital wedge in agriculture and the labor wedge in non-agriculture were especially important, relating to the above findings on the allocation of capital and labor in the prewar period.

Second, I simulate the model by assuming that prewar wedges in production remained unchanged in the postwar period, and find that fixing the wedges decreases the real GNP per worker by 16% per annum between 1947 and 1965. In particular, fixing the capital wedge in agriculture alone decreased real GNP per worker by 1% per annum. This amounts to about 327 billion yen in the year 1965 alone, which is roughly the same as the total government expenditure on the land reform (334 billion yen at 1965 prices) (Nochi Kaikaku Kiroku Iinkai, 1951). Therefore, the impact on postwar economic growth was considerable.

The present study contributes to the economic literature on property rights as well as that on structural transformation. First, this study relates to the literature on the economic consequences of secure property rights and tenancy.[7] For example, Hornbeck (2010) found that the improved security of farmland through the introduction of barbed wire fencing has a positive impact on agricultural development. Banerjee et al. (2002) also found that improving the security of the tenure of sharecroppers and regulating land rents have a positive effect on agricultural productivity. Rather than examining the effect of the improved security of property or the strengthening of tenancy rights, however, this paper examines the effect of the

[7] See, e.g., Besley and Ghatak (2010) and Fenske (2011) for a review. In a more recent work, Montero (2022) examined the effect of cooperative property rights by analyzing the land reform in El Salvador. In addition, Chari et al. (2020) found that the formalization of leasing rights in China increased the reallocation of land toward more-productive farmers.

ownership of secure property rights. Furthermore, the present study also examines the impact on structural transformation.[8]

This study also relates to the literature on structural transformation, and particularly to empirical studies relating structural transformation with agricultural development.[9] For example, Bustos et al. (2016) found that the labor-saving technological change in soy production in Brazil increased local industrial employment and outmigration in regions where adopting such technologies was potentially more profitable. Bustos et al. (2020) also found that the same shocks caused the outflow of capital (money) from regions where there was an increase in agricultural profits and savings, to other regions. This study complements these studies by examining the impact of property rights (land ownership) on structural transformation.[10] Regarding the latter, this paper studies the reallocation of capital (agricultural machines) in the opposite direction: from non-agriculture to agriculture during structural transformation.

Another strand of literature shows that relaxing labor mobility constraints facilitates the reallocation of labor (e.g., Hayashi and Prescott, 2008; Bryan et al., 2014; de Janvry et al., 2015; Nakamura et al., 2022). For example, de Janvry et al. (2015) found that obtaining certificates of property increases labor reallocation. This study stands on a similar motivation, but analyzes it from a different angle by focusing on constraints which would limit the use of capital in agriculture, which in turn would affect the allocation of labor.

This study also relates to the literature on capital intensification in agriculture. Hornbeck and Naidu (2014) found that, due to the outmigration of the black population caused by a flood in the American South, farm owners in the flooded area increased their capital intensity in agriculture. More recently, in a randomized controlled trial in India, Caunedo and Kala (2022) found that giving farmers rental vouchers to rent agricultural equipment increased the use of agricultural machines and decreased the labor use in production. The macro literature on capital deepening (Acemoglu and Guerrieri, 2008; Alvarez-Cuadrado et al., 2017) and automation (Acemoglu and Restrepo, 2018) are also related to the present work in this regard. Overall, this study provides new evidence on the use of capital in agriculture and the resulting replacement of labor, by analyzing the role of property rights in structural transformation.

Finally, the literature on barriers to technology adoption is also relevant to this study (Parente and Prescott, 1994, 2000).[11] As such a barrier, this paper focuses on land institutions.

[8] In this regard, this paper is also relevant to the recent literature analyzing the impact of changes in agrarian institutions from a historical perspective. Heldring et al. (2021) found that, compared with non-monastic parishes, monastic parishes after the dissolution of the monasteries in 16th century England fostered commercialization and industrialization in the long-run. In a related work, Markevich and Zhuravskaya (2018) examined the abolition of serfdom in 19th century Russia and found that it had a positive impact on grain productivity and industrial development Acemoglu et al. (2011) also find that institutional changes, which included the abolition of feudalism, due to the invasion of the French revolutionary armies, affected economic development. This study complements these previous analyses by examining the effect of land ownership, and by providing a new mechanism on labor and capital reallocation during structural transformation using post-WWII Japan as a testing ground.

[9] Herrendorf et al. (2014) provide a review of the macro literature.

[10] Erten and Leight (2021) also examine the effects of trade shocks on structural transformation.

[11] The literature on technology adoption is quite vast. See Foster and Rosenzweig (2010) for a review of the literature. In a recent work, Moscona and Sastry (2021) studied environmental dissimilarity as a barrier to the international diffusion of crop-specific biotechnology.

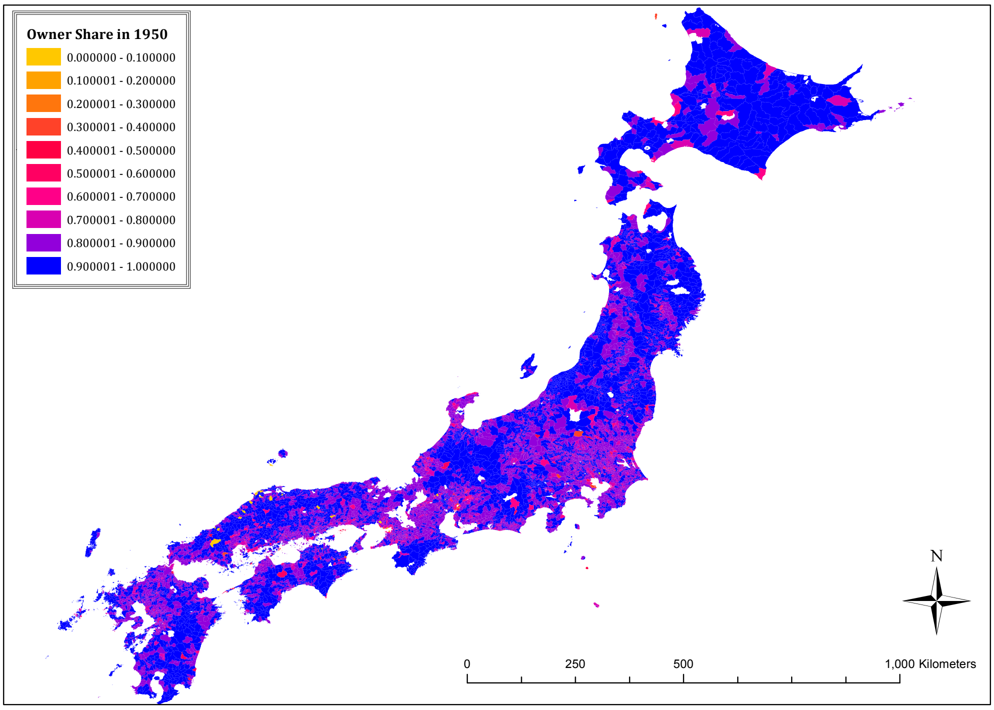


Figure 3: Distribution of Owner share after land reform

The rest of the paper is organized as follows. Section 2 briefly describes the historical background. Section 3 explains the sources of data and variables. Section 4 describes the empirical strategy. The results are shown in Section 5, and the underlying mechanism is discussed in Section 6. In Section 7, I calibrate a two-sector neoclassical growth model and conduct counterfactual simulations. Finally, Section 8 concludes the paper.

2 Background

2.1 Land reform

A historically large-scale land reform occurred between 1947 and 1950 in Japan. The reform was enforced by the Allies: it would have been impossible to implement such a massive land reform otherwise (Dore, 1959). The ownership of farmlands was redistributed from landlords to tenants with low prices. As a result, tenants suddenly became the owners of farmlands that they had cultivated. This change involved the property rights of nearly all (approximately 6 million) farm households. Accordingly, the share of tenanted farmlands decreased dramatically, and the share of owned farmlands (henceforth, owner share) increased in equal measure.

Figure 2 shows the distributional shift in the owner share by municipality. The white bars show the distribution before the reform, while the colored bars indicate the distribution after the reform. The average of owner share increased from 0.57 to 0.89 within just a few years.

The reform yielded a new spatial distribution of owner farming. Figure 3 shows the spatial distribution of the owner share across municipalities after the reform. The variation of the post-reform owner share was very different from that of the pre-reform owner share: the correlation between them is only 0.25. The emergence of such post-reform variation, rather than the conversion of all tenanted farmlands to owned farmlands was, in part, due to criteria introduced by the Allies as an act of clemency for landlords. I exploit this unique feature of the land reform in an empirical strategy. The Empirical Strategy section below provides more details.

During the reform, farmlands were purchased on behalf of prefectural governors. Prices were determined by multiplying fixed rental prices in 1945, by a particular multiplier according to the type of farmland.[12] There was also a monetary compensation for the purchases.[13]

On average, the government paid about 980 yen per tan (≈ per are) to a landlord of paddy fields, and paid about 580 yen per tan to a landlord of dry fields. For example, if a landlord had to sell 3 cho (≈ per hectare) of his/her tenanted dry fields, the price was less than 30,000 yen, which was, on average, less than a third of an annual salary of an industry worker in 1950.[14] Landlords were paid either in cash or in government bonds redeemable within 30 years at the annual interest of 3.6%.

Tenants paid the same price as the landlords' selling price to buy the farmland from the government, and it was paid either in cash or spread over thirty years at the annual interest of 3.2%. Given the postwar inflation until the end of 1940s and the fixed land price, land prices became cheaper and cheaper over time.[15] Therefore, most tenants could complete their payments within a year or two of purchase (Dore, 1959).

To complete the reform, the Agricultural Land Act (*Nochi Ho*) was enacted in 1952 to strictly regulate any further transactions involving farmlands.[16]

2.2 Agricultural mechanization

Agricultural mechanization in postwar Japan was started by small and convenient machines such as power tillers, and was later enhanced by large and powerful machines such as tractors.[17] Thus, there was a path dependency in the process of agricultural mechanization. The diffusion

[12] The multiplier was 40 for paddy fields and 48 for dry fields. Since the rental prices were somewhat less than 20 yen for paddy fields and 10 yen for dry fields on average, the price per tan was approximately 760 yen for paddy fields and 450 yen for dry fields. One tan is approximately ten are.

[13] The compensation was about 220 yen per tan for paddy fields and 130 yen for dry fields for about 3 cho (12 cho in Hokkaido Prefecture) of purchase at the maximum. One cho is approximately one hectare, or ten tan.

[14] The annual salary of a worker in a firm with 30 or more employees was about 100,000 yen in 1950, according to the National Tax Agency's Statistical Survey (*Minkan Kyuyo Jittai Tokei*).

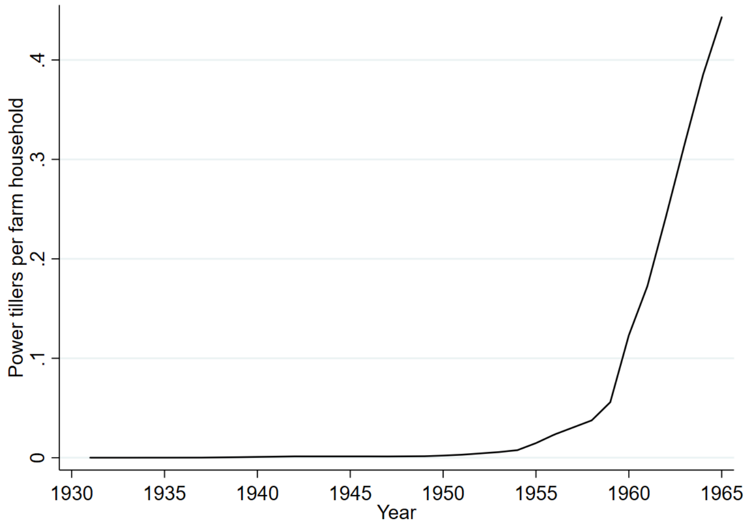
[15] For example, the value of goods equivalent to 30,000 yen in 1947 would be about 52,000 in 1948 (at the inflation rate of 73.2%), and finally about 65,000 in 1949 (25.3%). The price data were taken from the Statistics Bureau's Annual Report (*Syohisya Bukka Sisu Nenpo*). Note that the CPI was based on the prices in Tokyo, excluding imputed rents, and the average price between 1934-36 was set as the baseline.

[16] According to Dore (1958), the reason for enacting such a law was the following: "Many Western observers during the Occupation, suspicious of the apparent smoothness with which the reform was carried out, predicted that as soon as the Occupation troops were gone, 'the landlords would soon be back.' They have been proved wrong. The only post-Occupation legislation bearing on the land system has been the Agricultural Land Law of 1952 [...] which had the express purpose of freezing the Japanese system of land tenure in the state in which it emerged from the land reform" (p.185).

[17] The power tiller has several other names: rototiller, rotary tiller, hand tractor, walking tiller, garden tiller, etc. This paper uses the term "power tiller" to refer to two-wheel tractors and the term "tractor" to refer to four-wheel tractors. Two-wheel tractors are very common in Asia, except for India, where four-wheel tractors are more common (FAO, 2013).

(a) Tilling by hand

(b) Tilling by machine



(c) Penetration of power tillers, 1931-65

Notes: (a), (b): Change in farming methods. Both pictures were taken in 1956 near Hirosaki-shi, Aomori Prefecture. (c): The number of power tillers per farm household. In generating this graph, I interpolate the number of power tillers in 1932, 1934, 1936, 1938, 1940-41, 1943-46, 1948, 1952, and 1957, and the number of farm households in 1945, 1948, and 1956-59. Since the power tillers in and after 1960 are divided into two types, trailing type and automated type, I add these numbers together. Note that the data to plot the figure are different from the data used in the empirical analysis. These data include the long-run aggregate information at the country level.

Sources: (a), (b): Aomori Kyoudo Kan. (c): Ministry of Agriculture and Forestry's Annual Statistics.

Figure 4: Agricultural Mechanization

of power tillers occurred after the late 1950s, and that of tractors occurred after the late 1960s. The period of this study (1950-1965) corresponds to the former.

The introduction of the tillers constituted a turning point for modernizing Japanese agriculture (Hayami and Kawagoe, 1989). Before power tillers, farmers had typically tilled the soil by hand or using livestock. Figures 4 (a) and (b) show pictures taken in 1956 near Hirosaki-shi in Aomori Prefecture. In Figure 4 (a), three farmers use traditional farm equipment called *Sanbon-guwa* to till the soil. In Figure 4 (b), a farmer uses a power tiller to do the same job. Such machines effectively reduced the amount of human labor compared to prior agricultural production. Hayami and Kawagoe (1989) wrote:

> Previously, farm operations in Japan had been largely based on manual labor. Especially, land preparation for rice cultivation had been a very arduous task requiring

> labor of young male workers. With the introduction of power tillers it became possible for female or old-aged workers alone to keep on farming; this enabled young to middle-aged males in farm households to engage mainly in non-farm economic activities (p.227).

For example, Kajii (1965) found that a farm household owning 3 hectares of farmland in the Shonai Region in Yamagata Prefecture, which initially had four standing workers, reduced the number of the workers by two due to the adoption of power tillers.

The first power tillers were imported to Japan as early as the early 1920s. These included the power tillers of Simar from Switzerland and those of Utilitor and Beeman from the United States. However, this small wave of importation did not last long due to high prices and mismatch between the technology and soil conditions. Domestic machines also appeared as early as 1926; however, it was not until the late 1950s that the mechanization of agriculture began in earnest (Wada, 1979).

One of the key events for the change was the introduction of the "Merry Tiller" from the United States. Clayton Merry invented the power tiller known as the Merry Tiller in 1947, and he and his brother-in-law started commercializing them in Edmonds, WA. The machines were imported to Japan in 1952, and a Japanese agricultural machine maker started to sell them one year later.[18] The original power tillers had a 2 to 3 hp air-cooled high-speed engine with a simple structure, and were much lighter and cheaper than similar machines developed by Japanese manufacturers (Kako, 1987). However, the machines also had major defects, such as insufficient land cultivation depth, complicated operating procedures, and small engine sizes (Hokimoto, 1999).

The entry of the Merry Tiller greatly stimulated the research and development efforts of domestic agricultural machinery manufacturers such as Iseki, Kubota, Fujii, and Takeshita.[19] Such efforts made power tillers more efficient, powerful, and suitable for soil conditions in Japan (Wada, 1979; Hokimoto, 1999).

Further, in 1959, the agricultural machinery industry experienced a major shock known as the "Honda Whirlwind"—Honda Motor's F150, a power tiller with a 5 hp air-cooled engine, was born. A book providing the corporate history of Iseki, a rival company, vividly conveys the impact of this event (Iseki Noki Kabushiki Gaisha, 1989):

> So what kind of power tiller was Honda Motor's F150 that gave such a shock to the agricultural machinery industry? The two most important features of this machine were that it was a one-body type and that it was nearly half the price of conventional power tillers.
>
> All of the power tillers are [...] of a type in which an agricultural engine is mounted on the main body of the power tiller and is conducted by a belt. The F150, however, was of a type in which the engine was directly connected to the transmission case, and was an epoch-making machine that broke through the shell of the technology

[18] The machines were called "Merry Tailors" by the Japanese at the time.
[19] Fujii and Takeshita merged to form the Yanmar Agricultural Machinery Manufacturing Co., Ltd. in 1961.

Source: Asahi Shimbun.

Figure 5: Mass Migration from Rural Areas to Big Cities

> used by the power tiller manufacturers up to that time. The price was also unbelievably low, at 70,000 yen wholesale and 100,000 yen retail for the F150, compared with 150,000 to 160,000 yen for conventional power tillers (p.113).[20]

After the shock, Iseki and other manufacturers began to develop new models that could compete with Honda's power tillers in terms of price and performance.

Figure 4 (c) shows that the slope of the adoption curve of power tillers became steeper at the end of the 1950s, and steeper still after 1960. In addition to the introduction of new low-cost agricultural machines, the literature indicates two reasons behind the rapid change: first, the land reform (1947-1950) impacted the living standards and incentives of farmers; and second, the Agricultural Improvement Fund Subsidy Act (*Nogyo Kairyo Shikin Josei Ho*) (1956) and the Agricultural Modernization Fund Subsidy Act (*Nogyo Kindai ka Shikin Josei Ho*) (1961) supplied subsidized loans to farmers through agricultural financial institutions to assist those who wished to improve their farm management (Wada, 1979; Hokimoto, 1999).

These two reasons are not necessarily mutually exclusive, however—the new owner farmers might be more willing to take out subsidized loans to further improve their farm management. In the Mechanism section, I examine the interaction between land ownership and the membership of agricultural cooperatives, the major suppliers of loans for farmers.

2.3 Migration and structural transformation

Between 1955 and 1973, the Japanese economy grew at an average annual rate of more than 9%, and real GDP increased by about five-fold. During this period, the employment share of agriculture decreased from 39.7% to 15.3%, while those of industries and services increased from 23.7% to 34.2%, and from 26.5% to 33.2%, respectively.

The decline in agricultural employment was notably due to the outmigration of the young agricultural population from rural areas (Namiki, 1957). This social phenomenon in the 50s, 60s,

[20] The average agricultural income per farm household in 1960 was 187,000 yen, according to my data.

and 70s in Japan has been called "Mass Employment" (*Syudan Shushoku*): a mass migration of recently graduated students from rural areas to urban centers, and their subsequent employment in the manufacturing and service sectors. In particular, three metropolitan areas (Tokyo, Osaka, and Nagoya) received a large net immigration. In 1962, for example, about 25% (166,000) of those who had just graduated from junior high schools—and about 20% (122,000) of those who had just graduated from high schools—in the countryside began to work in these metropolitan areas (Ministry of Health, Labour and Welfare, 2005). Such young workers were often called "golden eggs," as they quickly gained skills at their companies and contributed to the growth of the economy. Figure 5 shows a typical group of such young people, clad in their school uniforms, arriving from Aomori Prefecture (i.e., the same prefecture as in Figures 4 (a) and (b)) and greeting their new employers in Tokyo in 1959.

The period of rapid adoption of power tillers (Figures 4 (d) and 1 (c)) and that of the rapid decline in agricultural employment (Figure 1 (a)) clearly correspond to each other. The diffusion of agricultural machinery was a crucial factor that made such a decline possible (Kajii, 1965; Hayami and Kawagoe, 1989).

3 Data

This section describes the data that are used in the empirical analysis. As mentioned in the Introduction, I use a novel dataset of municipalities between 1930 and 1965. In general, previous studies using Japanese data have relied mostly on data archived at a more aggregated level, such as by prefecture.[21] In part, this may be due to the difficulty of obtaining most disaggregated data.[22] Another reason may be the mergers of municipalities, which makes it hard for researchers to match municipalities across time to construct a panel dataset.[23] Thus, making a dataset at a disaggregated level like the one used in this study was challenging at first.

To overcome the first issue, I collected paper-based data in several libraries and ministries, and digitized them. To overcome the second issue, I used a geographic information system (GIS) technique to match the municipalities. In this latter process, I also created shapefiles of municipalities, which made it possible to keep track of the municipal boundary changes over time. The following subsection describes the source of the dataset and the variables used in empirical analyses. The procedure of making these variables is described in the Online Appendix. Finally, a summary table of main variables is provided at the end of the section.

[21] In 1965, for example, there were 46 prefectures, containing 3,466 municipalities including special districts.

[22] Many official statistics are archived at an aggregated level such as by prefecture. Even if disaggregated data are found, such data are often not digitized.

[23] The total number of municipalities declined from 10,560 in 1950 to 4,901 in 1955, to 3,598 in 1960, and to 3,466 in 1965. The major decline occurred between 1953 and 1955 after the enactment of the Act to Promote Mergers of Towns and Villages (*Chouson Gappei Sokushin Ho*) in 1953.

3.1 Data sources and variables

Land reform data

The data of land reform are from *Nochi Kaikaku Siryo Shusei (The Collection of Agricultural Land Reform Materials)* (Nochi Kaikaku Shiryo Hensan Iinkai, 1980). One of these volumes includes information on land areas for owned farmlands, tenanted farmlands, or other types of farmlands before and after land reform, i.e., 1945 and 1950, for every municipality except for those in Wakayama Prefecture and Okinawa Prefecture.[24] Using the data source, I constructed the following variables: *owner share*, *the total area of tenanted farmlands*, and *the average size of farmlands.*

Other agricultural data

Most of the agriculture-related variables were taken from the Agricultural Censuses for 1950, 1955, 1960, and 1965 (Norinsho, 1950, 1959b, 1960, 1965). The agricultural census started in 1950 after World War II, by adopting the World Agricultural Census scheme of the Food and Agriculture Organization of the United Nations (FAO), and has been conducted every five years since then. I digitized the booklet containing data at the municipality level for each prefecture and year, separately, except for the 1955 census, for which all the data were available in a single booklet. As agricultural machines, I use power tillers, or two-wheel tractors, in the analyses. As mentioned in the Background section, power tillers were very important for agricultural mechanization in the country and spread rapidly over the study period. Moreover, the number of power tillers was the only variable that was consistently available across census years. For agricultural income, I digitized the Statistics of Agricultural Income (Norinsho, 1962, 1968). This statistics started in 1960. Finally, the data on agricultural cooperatives were taken from Norinsho (1959a); this booklet reports the membership of agricultural cooperatives at a disaggregated level, but they are only available for the year 1958.

Using these sources, the following variables were constructed: *power tillers per farm household*, *migration-related variables*, *education-related variables*, *average farm sizes*, *agricultural income*, *the share of the membership of the agricultural cooperatives*, *the share of the agricultural population*, *the share of paddy fields*, and *the share of farm households using livestock.*

Demographic data

Demographic data were taken from the national censuses of 1930, 1950, 1960, and 1965. The census data have been digitized by a team of researchers at Tsukuba University (Yamamoto and Kishimoto, 2006; Takita et al., 2012; Sato and Kishimoto, 2014). Although a 1940 census exists, it does not contain sufficient information for use in this analysis. There was no census in 1955. I also consulted the Vital Statistics in 1947 to measure births before land reform (Department of Statistics and Investigation, 1949).

Using these sources, I constructed the following variables: *the share of the population aged*

[24] The data for Wakayama Prefecture are missing. Okinawa Prefecture was under the control of the United States until 1972.

15–19, *population*, and *the number of births*.

GIS data

Elevation data were taken from the Shuttle Radar Topography Mission (SRTM3) of the National Aeronautics and Space Administration (NASA). The SRTM3 gathered high resolution raster data of 3 arc-seconds, or about 90 meters. Agricultural suitability data were taken from the Global Agro-Ecological Zones (GAEZ) data of the FAO. The locations of train stations were taken from the National Land Numerical Information of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

Using such data sources, the following variables were constructed: *elevation*, *slope*, *agricultural suitability*, *distance to the nearest transportation*, and *distance to the nearest metropolitan area*.

Municipal boundaries

To merge the above data year-by-year to construct a panel dataset, it was necessary to deal with the issue of municipality mergers. Municipalities across years were matched using the following procedure.

First, the shapefile of municipal boundaries for 1950, 1955, 1960, and 1965 was taken from the National Land Numerical Information of MLIT. However; since the shapefile for 1930 was not available, I created the data for that year using the following technique. First, I obtained the shapefile of the 1995 administrative boundaries from Statistics Bureau of the Ministry of Internal Affairs and Communications. The file contained the high-resolution boundary polygons at a level finer than municipalities. Using the Database of Administrative Boundary Changes (*Gyosei kai Hensen Deta besu*), which was developed by a team of researchers at Tsukuba University and contained information on the municipality names to which each disaggregated polygon belonged in each year, the disaggregated polygons were aggregated at the municipality level to create a shapefile of municipal boundaries.[25] This technique enabled the construction of municipality polygons across time, including polygons for 1930.

Next, I chose the 1965 municipality as the unit of analysis because the municipalities in the data were most aggregated in that year. Second, municipalities in earlier years were matched with the 1965 municipalities. In this process, I first projected municipality polygons using the Sinusoidal projection, and computed land areas for every polygon. Then, I created the point data of the centroid of each polygon for the early census years, and assigned the computed value to each point. Spatially matching the point data with the 1965 polygon, these values were aggregated at the 1965 municipality level and were compared with actual values. Finally, the observations within five square kilometer differences were used to minimize the measurement errors.[26] In total, 2,905 municipalities (including those in Wakayama Prefecture) were

[25] Since information such as the year of merger was sometimes incorrect, I corrected it (a) by using the Comprehensive List of Changes in Municipality Names throughout Japan (*Zenkoku Shichosonmei Hensen Soran*) (Shichoson Jichi Kenkyukai, 2006), and (b) by comparing polygons with those available from the National Land Numerical Information of MLIT.

[26] I found that some municipalities were incorrectly matched by setting larger criteria.

	Mean	Std.dev.	Obs.
A. Dependent variables (by year)			
Share of population aged 15-19 (1930)	0.09	0.02	2844
Share of population aged 15-19 (1950)	0.10	0.01	2844
Share of population aged 15-19 (1960)	0.08	0.02	2844
Share of population aged 15-19 (1965)	0.09	0.02	2840
Power tillers per farm household (1950)	0.01	0.04	2831
Power tillers per farm household (1955)	0.01	0.02	2830
Power tillers per farm household (1960)	0.04	0.05	2816
Power tillers per farm household (1965)	0.08	0.09	2834
B. Treatment variable			
Owner share (1950)	0.89	0.06	2806
C. Control variables			
Pre-reform farmland size (cho)	0.33	0.61	2806
Tenanted farmland (cho, 1945)	671.04	805.43	2807
Share of agricultural employment	0.67	0.21	2831
Births	723.15	1089.65	2812
Mean elevation (meters)	278.71	298.26	2844
Mean slope	19.12	13.26	2844
Share of paddy fields	0.22	0.18	2831
Share of farm households using livestock	0.26	0.26	2831
Diff. in agricultural suitability index	0.03	0.16	2844
Dist. to nearest metropolitan area (kilometers)	240.14	224.51	2844
Dist. to nearest transportation (kilometers)	6.61	12.28	2844

Notes: 1 cho ≈ 1 hectare. See Section A.1 in the Online Appendix for a more detailed description of each variable. The values are shown before taking the logarithm.

Table 1: Summary Statistics of Main Variables

successfully matched, or about 84% of all municipalities in 1965.

3.2 Summary statistics

Summary statistics of the main variables are shown in Table 1.

The next section describes the empirical strategy.

4 Empirical Strategy

In the following analyses, I examined the likelihood of owner farmers adopting agricultural machines and sending their children to urban centers, as compared to tenant farmers. The main identification strategy uses a difference-in-differences (DID) estimation method with fixed effects. I compared municipalities with a high share of post-reform owner farmers to those with a low share of such farmers (or a high share of post-reform tenant farmers), and examined whether the former municipalities react differently vis-á-vis the latter when the new low-cost agricultural machines become available.

As mentioned in the Background section, the post-reform distribution of land ownership was affected by the upper limits set by the central bureaucracy prior to the land reform. Since the underlying formula was known, I controlled for potential confounders based on the formula in regressions. In addition, I also checked the parallel trends assumption and conducted various checks for robustness. Further, as an alternative estimation strategy, I also compared two adjacent municipalities along either side of the prefectural boundary, in order to exploit this unique feature of the land reform.

4.1 Empirical model

The main regression model is written as

$$y_{mpt} = \beta\, OwnerShare_{mp} \times Post_t + \sigma_m + \mu_t + \mathbf{x}_{mpt}\xi + \varepsilon_{mpt}, \tag{1}$$

for municipality m in prefecture p in census year t, where $OwnerShare_{mp}$ is the share of owner farmers after the land reform, $Post_t$ is a year dummy which takes the value of 1 in the years 1960 and 1965, i.e., after the introduction of Honda Motor's F150, and 0 otherwise, σ_m is municipality fixed effects, μ_t is year fixed effects, $\mathbf{x}_{mpt}$ is pre-treatment controls, which are the interaction between the pre-treatment variables and year dummies, and ε_{mpt} is the error term. In addition, prefecture-by-year fixed effects were added in some specifications as a robustness check. I clustered standard errors at the prefecture level because the initial shock (or upper limits, see below) was given at the prefecture level.

The main outcome variables were power tillers per farm household and the share of the population aged 15-19. The choice of these variables was motivated by the historical facts and the literature, as described in the Background section. For the former variable, I anticipated that the estimate of β becomes positive after the new low-cost machines become available, whereas it becomes negative for the latter variable.

To validate the identification strategy, the treated municipalities that had more owner farmers after the reform should have behaved similarly as the control municipalities, if the new low-cost machines had not become available. Although the assumption cannot be tested directly, I checked parallel trends and conducted various robustness checks.

Upper Limits

The choice of the baseline pre-treatment variables in equation (1) rests on a unique feature of the land reform, i.e., the upper limits set by the central bureaucracy before land reform. The upper limits set the maximum area of farmlands that each landlord in a particular area could keep after the reform, thereby affecting the post-reform distribution of owner share.

The introduction of such upper limits was initiated by a Commonwealth representative, Dr. MacMahon Ball, in conjunction with his economic advisor, Eric E. Ward, during the sixth meeting of the Allied Council.[27] The proposal allowed the landlords to keep a certain amount of tenanted farmlands which was set to 1 cho ($\approx$ 1 hectare).[28] The proposal was accepted by

[27] Kitamura (2020) describes this political process in more detail. There was clearly a dissonance between American-Commonwealth delegates and Russian delegates in terms of occupation policies. Russia announced reservations to Dr. Ball's proposal, for example.

[28] The value was proposed without any detailed calculation: "According to Dr. MacMahon Ball's explanation his reasoning was the following: it would be 'precipitous' to abolish tenancy altogether, hence the question is: how much should be left? Since the average size of holding is about 1 cho and since it is desirable that the tenants who remain should have a viable holding, 1 cho would seem to be the answer" (Dore, 1959, p.141).

the Supreme Commander for the Allied Powers Directive (SCAP) in Japan "as the basis on which the latter eventually worked out with the Japanese Ministry of Agriculture a plan of which they could approve" (Dore, 1959, p.137).

Based on the proposal, the government enacted the Law Concerning the Special Measures for the Establishment of Landed Farmers (*Jisaku no Sosetsu Tokubetsu Sochi Ho*) (Law of Landed Farmers) and the Amendment to the Farmland Adjustment Law (*Nochi Chosei Ho Kaisei Horitsu*). According to the Law of Landed Farmers, the average size of the *tenanted farmlands* of landlords was set to 1 cho, and the average size of their *managed farmlands*, i.e., the sum of tenanted and owned farmlands, was set to 3 cho, in all prefectures except for Hokkaido Prefecture, where these values were set to 4 cho and 12 cho, respectively. Thus, the farmlands that landlords could keep after the reform were regulated by the Law in terms of (a) the size of tenanted farmlands and (b) the size of managed farmlands.

The Ministry of Agriculture and Forestry (MAF) proposed upper limits for each prefecture p by using the following formula:

$$x_p = \left(\frac{L\sum_{k\in\kappa}A_k}{\sum_{k\in\kappa}a_kA_k}\right)\times a_p \quad \text{and} \quad z_p = \left(\frac{L'\sum_{k\in\kappa}B_k}{\sum_{k\in\kappa}b_kB_k}\right)\times b_p, \tag{2}$$

where a_p denotes the average size of landlords' tenanted farmlands, b_p the average size of their managed farmlands, A_k the total area of tenanted farmlands, B_k the total area of managed farmlands, L and L' the average land sizes specified in the Law of Landed Farmers (i.e., 1 and 3, respectively, for areas outside of Hokkaido Prefecture, and 4 and 12, respectively, for areas in Hokkaido Prefecture), and κ the set of prefectures. The value of x_p was computed using the data in 1940 and 1944, and then the average value between these years was obtained for each p, whereas the value of z_p was computed using the data in 1944 (Nochi Kaikaku Shiryo Hensan Iinkai, 1976).[29]

Then, upper limits at the municipality level were determined by the Prefectural Land Committees, and were approved by the Central Land Committee prior to the land reform, using the same formula replacing the prefectural values with the municipal values and replacing L and L' with prefecture values. In other words, the upper limits at the municipality level are *constrained* by those at the prefecture level in the sense that the average of the municipal upper limits in a prefecture should be equal to the upper limit of that prefecture.[30] Later, I will exploit this unique feature of the land reform as an alternative estimation strategy.

For example, if the area of a landlord's tenanted farmlands is 1 cho and the upper limit on the tenanted farmlands is 0.6 cho, then the landlord has to sell 0.4 cho according to the Law of Landed Farmers. Although the upper limits on tenanted and managed farmlands are

[29] It is easy to show that the weighted arithmetic mean of x_p (z_p), after multiplying each side by A_p (B_p), becomes L (L').

[30] The procedure was the following. First, the plan made by the MAF was sent to the Central Land Committee, and the Committee discussed the plan. The original plan was approved without changing values. Then each Prefectural Land Committee refined the plan, and set municipal upper limits within each prefecture. All changes and proposals required the approval of the Central Land Committee, which consists of 8 representatives of tenants and 8 representatives of landlords from the Prefectural Land Committees, 2 representatives from the peasant unions, and 5 university professors.

	Dependent variable:									
	Population share aged 15-19					Power tillers per farm household				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Owner share × Post	−0.070	−0.042	−0.048	−0.022	−0.018	0.104	0.127	0.111	0.105	0.098
	(0.020)	(0.014)	(0.012)	(0.008)	(0.006)	(0.037)	(0.030)	(0.026)	(0.022)	(0.023)
Municipality controls	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Additional controls	No	No	No	No	Yes	No	No	No	No	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality F.E.	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Prefecture-by-year F.E.	No	No	No	Yes	Yes	No	No	No	Yes	Yes
Control mean (1950)	0.10	0.10	0.10	0.10	0.10	0.01	0.01	0.01	0.01	0.01
R^2	0.16	0.38	0.51	0.63	0.68	0.22	0.26	0.40	0.48	0.51
Observations	8414	8396	8396	8396	8312	11195	11175	11175	11175	11063

Notes: Standard errors are clustered at the prefecture level. The dependent variable for Columns (1)-(5) is the share of the population aged 15-19, and that for Columns (6)-(10) uses power tillers per farm household. "Post" takes a value of 1 in and after 1960, and 0 otherwise. Columns (1) and (6) add year fixed effects. Columns (2) and (7) add pre-treatment municipality controls: the average size of farmlands, the total area of tenanted farmlands, and the share of the agricultural population, all interacted with year dummies. Columns (3) and (8) add municipality fixed effects, and Columns (4) and (9) add prefecture-by-year fixed effects. Columns (5) and (10) add additional pre-treatment municipality controls: population, the number of births, the share of paddy fields, elevation, slope, agricultural suitability, the share of farm households using livestock, distance to the nearest metropolitan area, and distance to the nearest transportation, all interacted with year dummies.

Table 2: Effects of Land Ownership on Local Demographics and Technology Adoption

distinguished in the formula, they are highly correlated in the data (99.5%). Therefore, one may simply regard them as the average size of farmlands before the land reform.

Based on the formula, I included the average size of farmlands, the area of tenanted farmlands, and the share of the agricultural population, interacted with year dummies, as baseline pre-treatment controls. In a later analysis, I also include other control variables as a robustness check.

The next section shows the estimation results.

5 Results

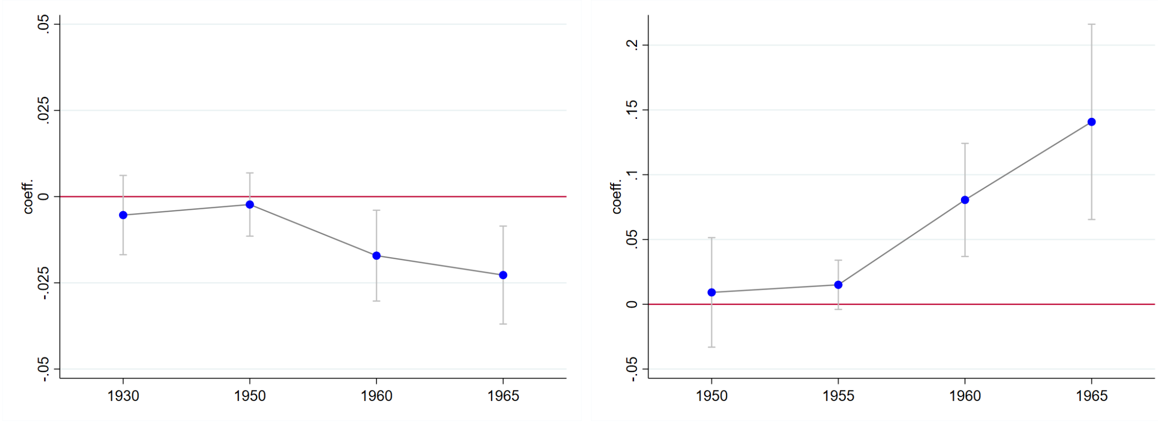
5.1 Effects on technology adoption and migration

5.1.1 Main results

Table 2 shows the average treatment effects of land ownership on local demographics and technology adoption. Columns (1)-(5) use the share of the population aged 15-19, and Columns (6)-(10) use power tillers per farm household, as the dependent variable. Columns (1) and (6) include only year fixed effects as controls. Columns (2) and (7) add baseline controls, Columns (3) and (8) add municipality fixed effects, and Columns (4) and (9) add prefecture-by-year fixed effects. In Columns (5) and (10), I add more controls.[31] Adding this relatively rich set of control variables barely changes the estimates, compared with those in Columns (4) and (9).

Figure 6 plots the estimates by year for each dependent variable using the specifications in Columns (5) and (10) in Table 2 without municipality fixed effects because the baseline year will be dropped by including them. The left figure, which uses the share of the population

[31] These are population, the number of births, the share of paddy fields, elevation, slope, agricultural suitability, the share of farm households using livestock, distance to the nearest metropolitan area, and distance to the nearest transportation. Tables A.1 and A.2 in the Online Appendix show the result when adding each variable separately.



(a) Population share 15-19 years old (b) Power tillers per farm household

Notes: The dependent variable of the left panel uses the share of the population aged 15-19, and that of the right panel is power tillers per farm household. Control variables are the same as those in Columns (5) and (10) in Table 2 without municipality fixed effects.

Figure 6: Estimated Coefficients by Year

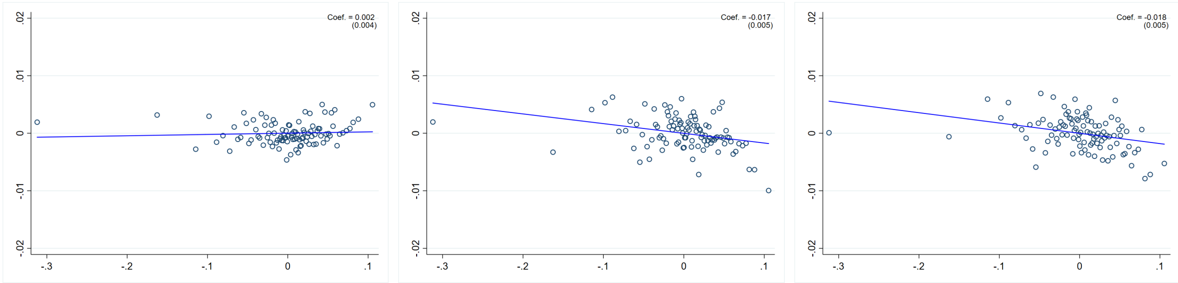
aged 15-19 as the dependent variable and adds the values in 1930 as well, shows that there was no systematic difference between the treatment and control groups in 1930 and 1950, but a difference started to appear in 1960 and 1965.[32] By contrast, the right figure, which uses the power tillers per farm household as the dependent variable, shows that there was no systematic difference between the two groups in 1950 and 1955, but a difference appeared in 1960 and 1965. The effects became somewhat larger in 1965, as compared to 1960. Therefore, although the parallel trends assumption cannot be tested directly, these results suggest the validity of this assumption.[33] Later, I also examine the possibility that other confounders (e.g., policies) bias the estimates, and show that this is less likely to be the case.

Figure 7 visualizes the results in an alternative way. To make these figures, I first took the difference of each dependent variable between particular years, except for 1950, since the values in that year were used as the baseline. Then, I ran a cross-sectional regression by regressing each of these variables on the control variables as in Columns (5) and (10) in Table 2, and took the residual. Similarly, I ran a cross-sectional regression by regressing the owner share on these control variables, and took the residual. Finally, these residuals were plotted against each other. The above panels in Figure 7 use the population share as the dependent variable, while the bottom panels in the same figure use technology adoption as the dependent variable. The figure clearly shows a pattern in which the slope, although nearly flat in 1950, becomes steeper for the 1950-60 difference in outcome variables and for the 1950-65 difference in outcome variables, for both dependent variables.

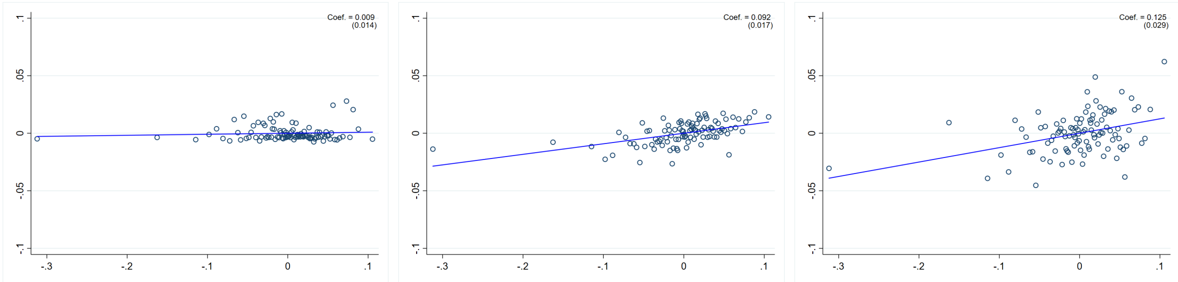
As a robustness check, I dropped samples to see if it would change the results in the

[32] The main regressions using the population share as the dependent variable do not include the values in 1930, so that the baseline year is consistently set as 1950 in all specifications. Adding 1930 yields the same results qualitatively.

[33] Figure A.1 in the Online Appendix shows the same figures without additional control variables; the patterns with and without additional control variables are similar.



(a) 1950 (b) 1960-1950 (c) 1965-1950



(d) 1950 (e) 1960-1950 (f) 1965-1950

Notes: The figures in the first row show partial correlation between the share of the population aged 15-19 (y-axis) and the share of owner farmers (x-axis), and those in the second row show partial correlation between power tillers per farm household (y-axis) and the share of owner farmers. Figures (a) and (d) use the outcome variables in 1950, Figures (b) and (e) use the difference in outcome variables between 1960 and 1950, and Figures (c) and (f) use the difference in outcome variables between 1965 and 1950. Thus, Figures (b), (c), (e), and (f) correlate the share of owner farmers with changes in the outcome variables within each municipality. The pre-treatment municipality controls are the average size of farmlands, the total area of tenanted farmlands, the share of the agricultural population, population, the number of births, the share of paddy fields, elevation, slope, agricultural suitability, the share of farm households using livestock, distance to the nearest metropolitan area, and distance to the nearest transportation.

Figure 7: Partial Correlation Between the Share of Owner Farmers and Local Demographics (Top) and Technology Adoption (Bottom)

Online Appendix. First, I dropped municipalities in Hokkaido Prefecture and 5 prefectures in the Tohoku region (i.e., Aomori, Iwate, Miyagi, Yamagata, and Fukushima Prefectures) and confirmed that the effects were not driven exclusively by these regions (Table A.3).[34] Second, I dropped the top and bottom percentiles of the owner share and found that this also did not change the results (Table A.4).

Related to the second exercise, I also estimated the effect for different quantiles of the owner share in the Online Appendix. As expected, the effect became larger as the owner share became higher (Table A.5). Taken together, these exercises indicate that the effects are less likely to be driven by particular observations.[35]

Overall, I found that the land ownership (owner share) increased the adoption of agricultural machines and decreased the share of young people in the population, after the introduction of new low-cost agricultural machines. Regarding the effect size, according to the estimates in Columns (5) and (10) in Table 2, one standard deviation increase in the treatment variable increased technology adoption by 1.06 standard deviations (or 792% of the mean value), and

[34] The average size of farmlands in, as well as the upper limits of, Hokkaido Prefecture is larger than those in other prefectures. It is also known that many young graduates outmigrated from the Tohoku region.

[35] I also ran Poisson pseudo-maximum likelihood regressions (Gourieroux et al., 1984; Santos Silva and Tenreyro, 2006). Table A.6 in the Online Appendix shows that the results still hold with this alternative estimation method.

	Dependent variable:					
	Pop. share aged 15-19			Power till. per farm hh.		
	(1)	(2)	(3)	(4)	(5)	(6)
Owner share × Post	−0.050	−0.033	−0.037	0.066	0.072	0.080
	(0.011)	(0.011)	(0.009)	(0.017)	(0.017)	(0.018)
Municipality controls	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	No	No	Yes	No	No	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Municipality F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture-by-year F.E.	No	Yes	Yes	No	Yes	Yes
Control mean (1950)	0.10	0.10	0.10	0.00	0.00	0.00
R^2	0.57	0.66	0.72	0.47	0.54	0.56
Observations	5235	5235	5169	6970	6970	6882

Notes: Standard errors are clustered at the municipality pair level. The dependent variable for Columns (1)-(3) is the share of the population aged 15-19 and for Columns (4)-(6) is power tillers per farm household. Columns (1) and (4) add year and municipality fixed effects, and pre-treatment municipality controls: the average size of farmlands, the total area of tenanted farmlands, and the share of the agricultural population, all interacted with year dummies. Columns (2) and (5) add prefecture-by-year fixed effects. Columns (3) and (6) add additional pre-treatment municipality controls; control variables for these two columns are the same as those in Columns (5) and (10) in Table 2.

Table 3: Effects of Land Ownership on Local Demographics and Technology Adoption Using Municipality Pairs

decreased the population share by 0.65 standard deviations (or 7% of the mean value), on average, as compared with the 1950 values. Looking only at the effects in 1965, these numbers became 1.22 and 0.75 standard deviations, respectively. Therefore, the effect size was considerable. One possible explanation for why the effect size was somewhat smaller for the population share than for technology adoption is that the land ownership might have affected technology adoption directly, whereas it might have affected local demographics only indirectly.

5.1.2 Comparing adjacent municipalities

Next, I employed an alternative estimation strategy using a unique feature of the land reform, i.e., upper limits. As described in the Empirical Strategy section, the upper limits of municipalities are constrained by those of the prefecture of those municipalities. Therefore, two adjacent municipalities along either side of the prefectural boundary which would otherwise have been very similar might have received different shocks during the land reform, precisely because these municipalities belonged to different prefectures.

First, I made a dataset which consists of pairs of municipalities—one on each side of the prefectural boundary. Then, I ran a cross-sectional regression, by regressing each variable, such as population, topography, agricultural suitability, and distance measures, on the owner share, while controlling for the baseline controls and pair fixed effects. Table A.7 in the Online Appendix shows that none of the estimates was statistically significant, indicating that these adjacent municipalities were very similar to each other.

Next, I ran a similar DID regression as in the main regressions but using the pairs of the municipalities. The results are shown in Table 3. Columns (1) through (3) use the share of the population aged 15-19, and Columns (4) through (6) use the power tillers per farm household,

	Dependent variable: Farm household members who migrated								
	Sons								Daughters
	New graduates		Other graduates						
	1st sons	2nd sons	1st sons			2nd sons			
	Aged: ≤17	≤17	Aged: ≤19	20-24	≥25	Aged: ≤19	20-24	≥25	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Owner share	1.713	7.088	1.858	0.184	0.378	7.926	12.176	10.963	46.658
	(1.179)	(3.299)	(0.795)	(1.018)	(1.600)	(2.185)	(2.942)	(3.980)	(17.815)
Municipality controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dependent variable mean	3.92	13.63	2.36	3.48	4.16	9.17	11.55	13.82	85.27
R^2	0.38	0.51	0.32	0.48	0.48	0.52	0.57	0.55	0.65
Observations	2752	2752	2752	2752	2752	2752	2752	2752	2752

Notes: Standard errors are clustered at the prefecture level. The dependent variable is the number of farm household members who migrated by February 1st, 1960. Columns (1) and (2) use the number of migrated sons who graduated in 1959 or 1960. Columns (3) through (8) use the number of migrated sons who graduated in earlier years. Column (9) uses the number of migrated daughters. The pre-treatment municipality controls are the average size of farmlands, the total area of tenanted farmlands, the share of the agricultural population, population, the number of births, the share of paddy fields, elevation, slope, agricultural suitability, the share of farm households using livestock, distance to the nearest metropolitan area, and distance to the nearest transportation.

Table 4: Correlation between Land Ownership and Migration Using Cross-Sectional Data

as the dependent variable. Columns (1) and (4) include the baseline controls, year fixed effects, and municipality fixed effects. Columns (2) and (5) add prefecture-by-year fixed effects, and Columns (3) and (6) add additional controls as before. I clustered standard errors at the pair level to take into account correlations within a pair.[36]

In general, although the samples were quite different from those used in the previous DID estimation, this alternative estimation method yielded estimates similar to those in Table 2, indicating that these estimates are arguably capture the causal effects.

5.2 Characterizing migrants

In this subsection, I characterize the migrants to obtain more detailed insights. I first used migration data and decomposed the effect on migration by the migrants' age, birth order, and gender. To do so, I regressed the number of migrants in each category on the owner share and control variables. Since the data were only available in 1960, I ran only cross-sectional regressions and I show only associations between these variables.

Table 4 shows the results. The dependent variable in Columns (1) through (8) is the number of migrated sons, while that in Column (9) is the number of migrated daughters.[37] "New graduates" refers to the migrants who just graduated from junior high schools or high schools in 1959 or 1960, i.e., at the time the agricultural census was being conducted.

Overall, the above results show that the migrants were mainly second or younger sons, and daughters. The results also correspond to the historical facts described in the Background section: those who outmigrated from the countryside in the 1950s and 1960s were young, second or younger sons, and daughters. These results are likely to reflect the primogeniture culture in Japan. In such a culture, the eldest sons usually inherit the family lineage, while the second

[36] Clustering at, e.g., the prefecture level is not possible because of the data structure.

[37] Unfortunately, the information for daughters is not as detailed as that for sons in the original data.

	Dependent variable: Farm hh. members in higher education				
	Male			Female	
		Migrants are Sons			Migrants are Daughters
		New grad.	Other grad.		
	(1)	(2)	(3)	(4)	(5)
Owner share	46.662			21.918	
	(44.653)			(37.581)	
Owner share × D(Migrants > median)		−347.035	−308.964		−375.306
		(110.516)	(97.645)		(111.051)
Owner share × D(Migrants ≤ median)		175.038	191.351		133.597
		(42.242)	(45.463)		(35.440)
D(Migrants > median)		452.766	447.879		443.187
		(108.370)	(100.202)		(104.256)
Municipality controls	Yes	Yes	Yes	Yes	Yes
Prefecture F.E.	Yes	Yes	Yes	Yes	Yes
Dependent variable mean	177.245	177.245	177.245	153.976	153.976
H0: b[Owner share × D(Migrants > median)] + b[Owner share × D(Migrants ≤ median)] = 0 (p-value)		0.150	0.274		0.046
R^2	0.66	0.67	0.67	0.64	0.65
Observations	2752	2752	2752	2752	2752

Notes: Standard errors are clustered at the prefecture level. The dependent variable is the number of farm household members who were studying at a high school or a higher educational institution in February, 1960. "D(Migrants > median)" is an indicator variable which takes a value of 1 if the number of migrants is above the median value, and 0 otherwise. "D(Migrants ≤ median)" is 1 minus this variable. The pre-treatment municipality controls are the same as in Table 4.

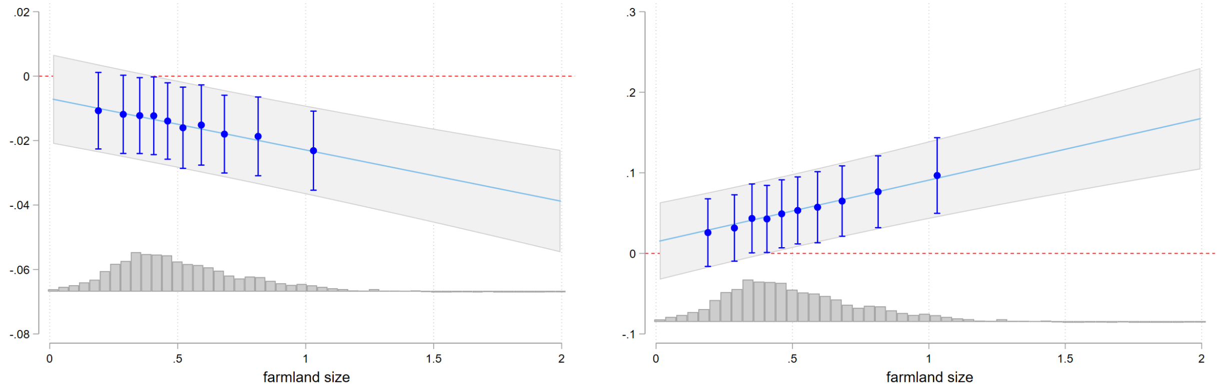
Table 5: Correlation between Land Ownership and Education Using Cross-Sectional Data

or younger sons, and daughters, do not. Interestingly, however, according to Column (3), the eldest sons also migrated if they were young.[38]

Next, relating to the argument on the role of human capital in industrialization (e.g., Mokyr, 2010), I examine whether these migrants continued their study or started to work after migration. To do so, I used the number of farm household members who had been studying in high school or a higher educational institution, according to the 1960 agricultural census. Since it was not possible to know how many of them had actually outmigrated, I created dummy variables based on the median value of the following migration variables: the number of male migrants who are less than 18 years old (for new graduates), the number of male migrants who are less than 20 years old (for other graduates), and the number of female migrants, using the same migration data as above. Then, I interacted the treatment variable with each of these dummies.

Table 5 shows the results; the dummy variable itself is included as an additional control in the regressions. It can be seen that the effect of land ownership is negative in the high migration areas, whereas it is positive in the low migration areas. These estimates offset each other for male migrants, while the negative effect dominates for female migrants. At least, I did not find strong evidence suggesting that these migrants continued studying in higher educational institutions. Rather, the above finding is consistent with the notion that the migrants accumulated their skills in the manufacturing and service sectors through learning-by-doing (e.g., Matsuyama, 1992).

[38] In a related work, Porzio et al. (2021) study the role of cohort effects in structural transformation.



(a) Population share 15-19 years old (b) Power tillers per farm household

Notes: The dependent variable in the left panel is the share of the population aged 15-19, and that in the right panel is power tillers per farm household. Control variables are the same as in Columns (5) and (10) in Table 2. I exclude municipalities in Hokkaido Prefecture to make the samples more comparable. To make the figures, I used the "binning estimator" (Hainmueller et al., 2019), in which the average farm size is divided into ten bins using percentiles.

Figure 8: Heterogeneous Effects by Farm Size

5.3 Heterogeneous effects by farm size

With reference to recent studies about the relationship between farm sizes and agricultural productivity (e.g., Foster and Rosenzweig, 2011, 2022; Adamopoulos and Restuccia, 2014), I examined the heterogeneous effects of land ownership by farm size. To do so, I employed the "binning estimator" (Hainmueller et al., 2019), in which the average farm size in 1950 is divided into ten bins using percentiles. Then, the marginal effect is computed for each bin. To make more sense of the comparisons, I dropped the municipalities in Hokkaido Prefecture, because the average farm size tends to be larger in that prefecture.[39]

Figure 8 shows the results. They indicate an interesting heterogeneity by farm size, although the differences are not statistically significant: the effects of land ownership on both dependent variables—namely, adopting machines and reallocating labor—tend to be larger for municipalities with a larger average farm size. Moreover, the effects are more or less linear.

The limited nature of this intriguing evidence of the complementarity between farm size and land ownership may be attributable to the rather small size of the average Japanese farm. For example, the average farm size in 1965 was 2.60 hectares (standard deviation: 1.70) in Hokkaido Prefecture, while the average farm size for the other prefectures combined was only 0.58 hectares (standard deviation: 0.28), according to the data used in the empirical analysis. This may reflect the historical background of Japan: in order to freeze the distribution of farmland after the land reform, the above-mentioned Land Act strictly regulated the consolidation of farmland until 1962, when the ceiling on land ownership was removed. Nonetheless, these sizes are closer to the farm sizes commonly observed around the world today, especially in low-income countries. Indeed, according to the FAO, small farms (less than 2 hectares) account for 84% of all farms

[39] The Online Appendix includes the results without excluding these municipalities, which show similar patterns (Figure A.2).

	Dependent variable: Farm size	
	(1)	(2)
Owner share × 1960	0.014	−0.048
	(0.075)	(0.066)
Owner share × 1965	0.126	−0.043
	(0.151)	(0.070)
Municipality controls	Yes	Yes
Additional controls	Yes	Yes
Year F.E.	Yes	Yes
Municipality F.E.	Yes	Yes
Prefecture-by-year F.E.	Yes	Yes
Dropped	None	Hokkaido
Control mean (1950)	0.61	0.54
R^2	0.48	0.34
Observations	8295	7845

Notes: Standard errors are clustered at the prefecture level. The dependent variable is the average farm size. Control variables are the same as in Columns (5) and (10) in Table 2. Column (2) drops Hokkaido Prefecture.

Table 6: Effects of Land Ownership on Farm Size

in the world (Lowder et al., 2016).

Not surprisingly, scale economies using bigger agricultural machines such as four-wheel tractors and combines did not start functioning until the late 1960s (Hayami and Kawagoe, 1989). Regarding this point, I considered that it would be worth examining whether land ownership changed the average farm size, because if scale economies had been at work, owner farmers would have increased the size of their farm operations.

Table 6 shows the results. To take into account the amendment of the Land Act, I split the effects between 1960 and 1965, the latter of which is considered part of the post-amendment period. The results in Column (1) indicate that land ownership did not affect the average farm size, although the coefficient became slightly larger in 1965. Dropping Hokkaido Prefecture in Column (2) does not significantly change the results, except that the sign of the coefficients becomes negative. Thus, as previous studies have found, the scale economies were less likely to be functioning in the study period.

5.4 Welfare

Finally, I investigated the welfare impact of land ownership on farm households using agricultural income. Since the *Statistics of Agricultural Income* started in 1960, it was not possible to obtain the agricultural income in earlier years. Thus, I first associated the owner share with agricultural income in 1960 and 1965, respectively, using the cross-sectional regressions. Then, although both of these years are in the post-treatment period, I took the difference in agricultural income between these years, and estimated the effect on the within-municipality income changes.

Table 7 shows the results. Columns (1) and (2) show that the owner share is associated positively with agricultural income in 1960 and 1965. Column (3) also shows that the owner share increased the agricultural income between these years. Regarding the effect size, one

	Dep. variable: Agricultural income		
	1960	1965	Difference
	(1)	(2)	(3)
Owner share	466.398	676.172	217.251
	(86.834)	(147.795)	(72.514)
Municipality controls	Yes	Yes	Yes
Prefecture F.E.	Yes	Yes	Yes
Dependent variable mean	341.44	515.67	174.10
R^2	0.68	0.66	0.51
Observations	2762	2764	2756

Notes: Standard errors are clustered at the prefecture level. The dependent variables are agricultural income in 1960 (Column (1)) and 1965 (Column (2)), and the difference in agricultural income between these years (Column (3)). The pre-treatment municipality controls are those in Table 4.

Table 7: Effects of Land Ownership on Agricultural Income

standard deviation increase in the treatment variable increases the agricultural income by 12.90, or about 7% of the dependent variable mean.[40]

6 Mechanism

Why were owner farmers more likely to adopt agricultural machines than tenant farmers? This section discusses the mechanism underlying the above findings.

The existing literature finds that the power structure in rural societies affects agricultural investment and human-capital promoting institutions (Banerjee et al., 2002; Goldstein and Udry, 2008; Galor et al., 2009). In Japan, the hierarchical relationship between landlords and tenants is often based on a type of family lineage called *honke-bunke*: in this system, the landlord is from the "main" household of a family lineage (*honke*), and tenants are from the "branch" households (*bunke*), or the descendants, of the same lineage. In addition to such a relationship based on a blood connection (*ketsuen*), there is a similar hierarchical relationship based on a territorial connection (e.g., village leaders and peasants living in the same small community) (*chien*).

Due to this hierarchical structure, the tenants could only hope to secure food after paying the rent, and could not hope to be richer than the landlord. This restrictive system has often been considered socially repressive, and even though the land rents were often fixed, the system exacted psychological costs on the tenants (Kondo, 1975; Ouchi, 1975). Not surprisingly, the landlords were not interested in investing in the farm management of their tenants.

The plight of the tenants, and their relationships with their landlords, were seen by the Allies as warranting adjustment. The land reform initiated by the Allies was meant to empower the tenants and democratize rural societies. For example, a directive sent from Douglas MacArthur to the Japanese authority, known as "MacArthur's Peasant Liberalization Directive," states

[40] In the Online Appendix, I also show similar results using agricultural income *per farm household* (Table A.8).

	Dependent variable:		
	Coop share	Pop. share aged 15-19	Power till. per farm hh.
	(1)	(2)	(3)
Owner share	0.045		
	(0.048)		
Owner share × D(Coop share > median) × Post		−0.025	0.139
		(0.008)	(0.030)
Owner share × D(Coop share ≤ median) × Post		−0.011	0.075
		(0.007)	(0.029)
D(Coop share > median) × Post		0.014	−0.050
		(0.009)	(0.031)
Municipality controls	Yes	Yes	Yes
Additional controls	N.A.	Yes	Yes
Year F.E.	N.A.	Yes	Yes
Municipality F.E.	N.A.	Yes	Yes
Prefecture-by-year F.E.	N.A.	Yes	Yes
Dependent variable mean	0.200		
Control mean (1950)		0.101	0.006
H0: b[Owner share × D(Coop share > median) × Post] = b[Owner share × D(Coop share ≤ median) × Post] (p-value)		0.162	0.076
R^2	0.20	0.68	0.51
Observations	2753	8204	10939

Notes: Standard errors are clustered at the prefecture level. The dependent variable for Column (1) is the share of the membership of agricultural cooperatives, that for Column (2) is the share of the population aged 15-19, and that for Column (3) is power tillers per farm household. "D(Coop share > median)" is an indicator variable which takes a value of 1 if the share of the membership is above the median value, and 0 otherwise. "D(Coop share ≤ median)" is 1 minus this variable. The pre-treatment municipality controls for Column (1) are the same as those in Table 4, and those for Columns (2) and (3) are the same as those in Columns (5) and (10) in Table 2, respectively.

Table 8: Heterogeneous Effects of Land Ownership: Membership of Agricultural Cooperatives

that:

> In order [...] [to] remove economic obstacles to the revival and strengthening of democratic tendencies, establish respect for the dignity of men, and destroy the economic bondage which has enslaved the Japanese farmer to centuries of feudal oppression, the Japanese Imperial Government is directed to take measures to insure that those who till the soil of Japan shall have a more equal opportunity to enjoy the fruits of their labor. [...] The purpose of this order is to exterminate those pernicious ills which have long blighted the agrarian structure of a land where almost half the population is engaged in husbandry.

The land reform dramatically changed rural society through the redistribution of farmlands, i.e., the source of power, from the landlords to the tenants, thereby creating new independent farmers.

These independent farmers, who were more likely to be motivated to improve their farm management, adopted the new low-cost agricultural machinery as it became available (Kondo, 1975; Ouchi, 1975). Further, such changes in the behavior of farmers might have also been boosted by subsidized loans through agricultural financial institutions (Wada, 1979; Hokimoto, 1999), because owner farmers might have been able to use their farmlands as collateral for taking loans (de Soto, 2000; Besley et al., 2012). Such practices were in fact taking place (Kondo, 1975).

In order to investigate this channel of potential financial sources for owner farmers, I examined the interaction between land ownership and the membership in agricultural cooperatives, the major suppliers of loans for farmers.[41]

The results are shown in Table 8. Column (1) examines a cross-sectional association between the share of coop membership, measured in 1958, and land ownership. I did not find any significant association between them, indicating that land ownership did not increase or decrease the membership in agricultural cooperatives. Next, I split the effect of land ownership into those in areas with high and low percentages of agricultural population belonging to agricultural cooperatives based on the median value. I found evidence suggesting that the effects are larger in areas where a higher fraction of the agricultural population belonged to agricultural cooperatives, although the difference was not statistically significant for the share of the young population. At least, the effects were more likely to appear in such areas than in other regions. By contrast, the effect of the agricultural cooperatives *per se* is not statistically significant, according to the results in the table. In summary, although the results are only suggestive, the table shows a sort of synergy between land ownership and membership in agricultural cooperatives, which would be consistent with the narrative outlined above.

Finally, there is another possibility—i.e., that owner farmers were able to invest more than tenant farmers because the former no longer paid high land rents to landlords. However; this is unlikely to have been the main driving force in the present analysis, because the rents were also regulated due to the land reform. Although the land rents constituted about 42% of the total cost before the reform (1937), they became only about 6% of the total cost after the reform (1956) (Kondo, 1975). Thus, the tenant farmers were also facing low rents after the reform.

7 Quantifying the Impact of Reallocation

In this final section before concluding the paper, I assess the overall impact of the reallocation of not only labor, but also capital, on economic growth. As described in the Background section, Japan has experienced a rapid growth since late 1950s. To quantify how much the reallocation contributed to the postwar economic miracle, I used a two-sector neoclassical growth model, quantified prewar wedges, and conducted counterfactual simulations using the wedges. The rationale for assessing the impact using a growth model, rather than, e.g., estimating the impact on the local economy using regressions, is that structural transformation, at least in Japan, is associated with factor reallocation across locations. I intend to quantify the overall impact of such reallocation in this section.

7.1 The model

The model is based on Cheremukhin et al. (2016), who studied the structural transformation of Russia between 1885-1940. The economy has a population N_t. Preferences over consumption

[41] Although a more direct measure of credit access such as balance sheets would be ideal, to the author's best knowledge, such data are not available for the period of this study.

sequences of agricultural and non-agricultural goods $\{c_{at}, c_{nt}\}$ for a stand-in household are given by

$$\sum_{t=0}^{\infty} \beta^t \frac{U(c_{at}, c_{nt})^{1-\rho} - 1}{1-\rho}, \tag{3}$$

where $\beta \in (0,1)$ is a discount factor and $\rho \geqslant 0$ is the inter-temporal elasticity of substitution. The utility function is defined as

$$U(c_{at}, c_{nt}) = \left[\psi^{\frac{1}{\sigma}}(c_{at} - \bar{c}_a)^{\frac{\sigma-1}{\sigma}} + (1-\psi)^{\frac{1}{\sigma}}(c_{nt})^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \tag{4}$$

where $\psi \geqslant 0$ is the consumption share of agricultural goods and $\sigma > 0$ is the elasticity of substitution between the two consumption goods. The existence of the subsistence term $\bar{c}_a \geqslant 0$ allows that the changes in income can possibly change the expenditure shares of these consumption goods. In particular, the non-homotheticity assumption (i.e., $\bar{c}_a > 0$) explains the demand-side mechanism of structural transformation driven by income changes. In addition, the supply-side mechanism of structural transformation driven by relative price changes kicks in when $\sigma \neq 1$ and the total factor productivity (TFP) of two sectors grows unevenly. The household is endowed with one unit of time and an initial capital stock, $K_0 > 0$.

The representative firm in each sector produces outputs Y_{jt} using the Cobb-Douglas technology:

$$Y_{jt} = A_{jt} K_{jt}^{\theta_{Kj}} L_{jt}^{\theta_{Lj}}, \qquad j \in \{a, n\}, \tag{5}$$

where A_{jt} is TFP, K_{jt} is capital, L_{jt} is labor, and θ_{Kj} and θ_{Lj} are the capital and labor shares in sector j, respectively. The capital and labor shares satisfy $\theta_{Kj} + \theta_{Lj} \leqslant 1$. Land is fixed and its share in production is $1 - \theta_{Kj} - \theta_{Lj}$.[42]

The capital and labor markets clear in equilibrium:

$$K_t = K_{at} + K_{nt} \tag{6}$$

and

$$L_t = L_{at} + L_{nt}. \tag{7}$$

The law of motion for the aggregated capital stock takes the form

$$K_{t+1} = (1-\delta)K_t + I_t, \tag{8}$$

where $\delta \in (0,1)$ is the depreciation rate and I_t is investment. Assuming that investment is made by the non-agricultural sector, feasibility conditions in the two sectors are written by

$$N_t c_{at} + E_{at} = Y_{at} \tag{9}$$

and

$$N_t c_{nt} + I_t + G_t + E_{nt} = Y_{nt}, \tag{10}$$

[42] I assumed that land is fixed and its contribution is absorbed in the TFP.

where G_t is the government expenditure, and E_{jt} for $j \in \{a,n\}$ is the net exports of goods j.[43]

Recall that, as seen in the Introduction, labor was relatively abundant and capital was scarce in the prewar period. In addition, in the empirical section, I show that land ownership increased technology adoption and outmigration. To further understand these findings, I compute wedges in the prewar period. In particular, using the optimality conditions, wedges are calculated as

$$\begin{aligned} \tau_K &= \frac{MPK_{nt}}{p_t MPK_{at}} && (11) \\ &= \frac{U_{nt}}{U_{at}} \frac{MPK_{nt}}{MPK_{at}} && (12) \end{aligned}$$

and

$$\begin{aligned} \tau_L &= \frac{MPL_{nt}}{p_t MPL_{at}} && (13) \\ &= \frac{U_{nt}}{U_{at}} \frac{MPL_{nt}}{MPL_{at}}, && (14) \end{aligned}$$

where τ_K and τ_L are the inter-sectoral capital and labor wedge, respectively, p_t is the price for the agricultural goods relative to the non-agricultural goods, MPK_{jt} and MPL_{jt} are the marginal product of capital and labor for sector j, respectively, and U_{jt} is the marginal utility of consuming goods j.

The wedges are further decomposed as

$$\tau_K = \underbrace{\frac{U_{nt}}{U_{at}/p_t}}_{\text{consumption component}} \times \underbrace{\frac{MPK_{nt}/r_{nt}}{p_t MPK_{at}/r_{at}}}_{\text{production component}} \times \underbrace{\frac{r_{nt}}{r_{at}}}_{\text{mobility component}} \tag{15}$$

and

$$\tau_L = \frac{U_{nt}}{U_{at}/p_t} \times \frac{MPL_{nt}/w_{nt}}{p_t MPL_{at}/w_{at}} \times \frac{w_{nt}}{w_{at}}, \tag{16}$$

where r_{jt} and w_{jt} for $j \in \{a,n\}$ are the rental and wage rate, respectively. The consumption component is the optimality condition for consumers, whereas the production component is the optimality condition for firms. Each component becomes 1 if there is no wedge. In the following analyses, I use the notation of τ_C for the consumption component, τ_{PK} and τ_{PL} for the production component in terms of capital and labor, respectively, and τ_R and τ_W for the mobility component in terms of capital and labor, respectively. Therefore, $\tau_K = \tau_C \times \tau_{PK} \times \tau_R$ and $\tau_L = \tau_C \times \tau_{PL} \times \tau_W$.

7.2 Data

This subsection describes how I constructed the dataset for simulation. I focused on the period between 1885 and 1965. The baseline dataset was taken from Hayashi and Prescott (2008). This

[43] These conditions were also used in Cheremukhin et al. (2016).

Parameter	Description	Value
θ_{Ka}	Capital share (agriculture)	0.144
θ_{Kn}	Capital share (non-agriculture)	0.333
θ_{La}	Labor share (agriculture)	0.545
θ_{Ln}	Labor share (non-agriculture)	0.667
β	Discount factor	0.9
σ	Elasticity of substitution	1
ρ	Intertemporal elasticity	0
ψ	Asymptotic share of agriculture	0.23
$\bar{c}_a$	Subsistence level	40.675
δ	Depreciation rate	0.051

Table 9: Model Parameters

included variables on population, output, non-agricultural capital, and labor for the prewar and postwar periods. I extended this dataset using *Long-Term Economic Statistics* (Ohkawa et al., 1982, 1978; Yamazawa and Yamamoto, 1979), Ohkawa and Shinohara (1979), and the MAF's statistics (Norinsho, 1969, 1971).

First, I extended the series of agricultural capital using Ohkawa et al. (1978), which is the original source of Hayashi and Prescott (2008), for 1941-1962, and using Norinsho (1969, 1971) for 1962-1965. Since the latter values were measured in current prices, I deflated them using 1934-1936 prices as in the baseline data series, and spliced them into the data series of Ohkawa et al. (1978) at 1962.

Government expenditures for the prewar period were taken from Hayashi and Prescott (2008). I used the same method as they did to extend the data for the postwar period: I took the sum of government purchases and the gross capital formation of the public sector, net of depreciation, and then deflated the current values to 1934-1936 prices. These data were taken from Ohkawa and Shinohara (1979) and Ohkawa et al. (1982), which were the original sources of Hayashi and Prescott (2008).

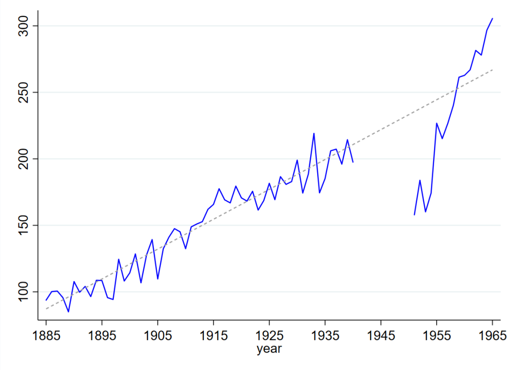
Exports and imports data were from Yamazawa and Yamamoto (1979). I deflated the current values to 1934-1936 prices to match the prewar data.

7.3 Parametrization

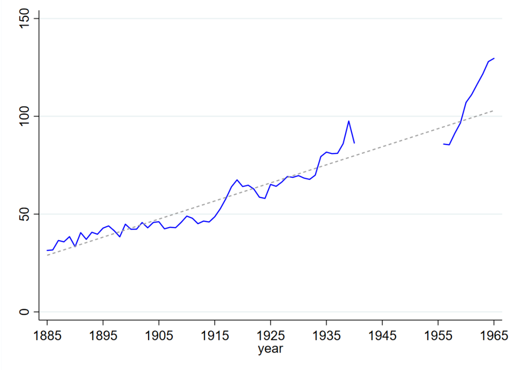
The values of parameters were computed from the data or taken from the literature, but these parameter values were broadly consistent with those in the literature of structural transformation using similar model settings (e.g., Hayashi and Prescott, 2008; Cheremukhin et al., 2016).

First, the subsistence level of agricultural consumption was set as 80% of the agricultural consumption in 1885. Under the commonly assumed Stone-Geary utility function ($\sigma = 1$), the optimality condition for consumers yields

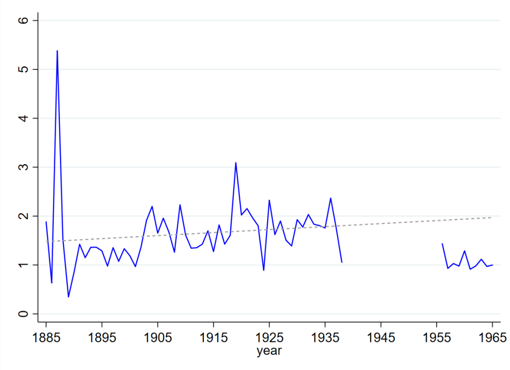
$$\frac{\psi}{1-\psi} = \frac{p_t(c_{at} - \bar{c}_a)}{c_{nt}}. \tag{17}$$



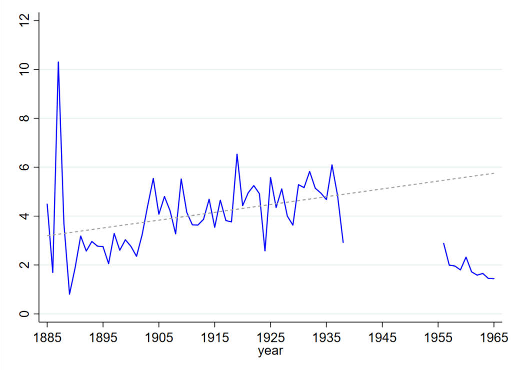
(a) Agricultural TFP



(b) Non-agricultural TFP



(c) Capital wedge (τ_K)



(d) Labor wedge (τ_L)

Figure 9: Sectoral TFPs and Wedges in Japan, 1885-1965

I took the prewar average of the right-hand side values to compute the asymptotic consumption share of agriculture (Hayashi and Prescott, 2008).

The capital and labor share in the non-agricultural sector were set as the customary values of 1/3 and 2/3 by assuming that the land is the sole production factor for agriculture. The capital share in the agricultural sector is the prewar average of the ratio of capital input to the gross output in the agricultural sector. This, as well as the labor share, were taken from Hayashi and Prescott (2008). Finally, the depreciation rate was the ratio of real depreciation to real capital stock in 1940, which was also from the study by Hayashi and Prescott.

The model parameters are summarized in Table 9.

7.4 Wedges in Japan

Figure 9 shows TFPs and wedges in Japan between 1885-1965, according to the model. The dashed lines represent linear prewar trends (1885-1939). Although both τ_K and τ_L had slightly increasing trends in the prewar period, they decreased in the postwar period, when TFPs were also increasing.

Next, I decomposed prewar wedges using equations (15) and (16). Since the data on rental rates were not available, I did not decompose the production and mobility components for capital. Alternatively, if capital is assumed to move across sectors freely, the mobility component for capital is always 1.

Figure 10 shows the results. First, the consumption and mobility components of wedges

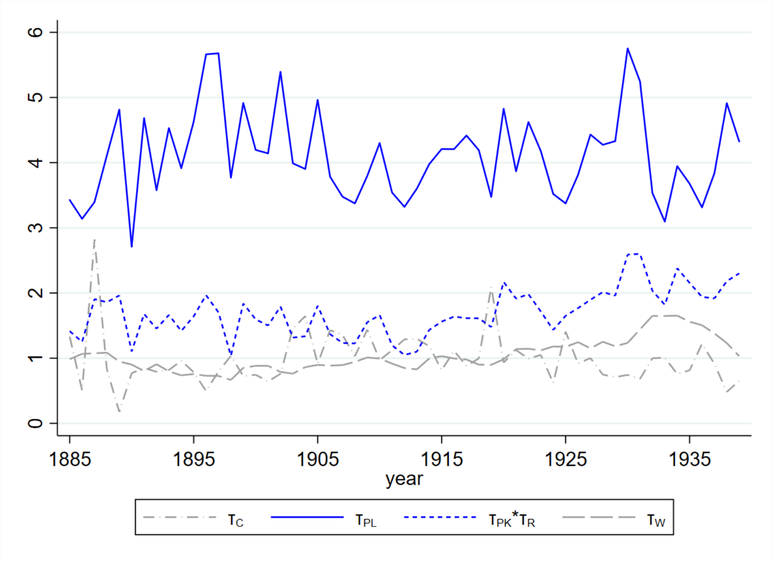


Figure 10: Decomposition of Prewar Wedges in Japan, 1885-1939

were negligible.[44] For example, the mobility component for labor in the equation was nearly 1, meaning that it was not the labor market wedges that lowered the mobility of labor in the prewar period. By contrast, the production components of the wedges (τ_{PK} and τ_{PL}), especially the component for labor, were relatively high, implying that it was the production side which caused the misallocation in the prewar period. In the following, I simulate the model in which these production wedges are assumed to remain unchanged in the postwar period.

7.5 Counterfactual simulations

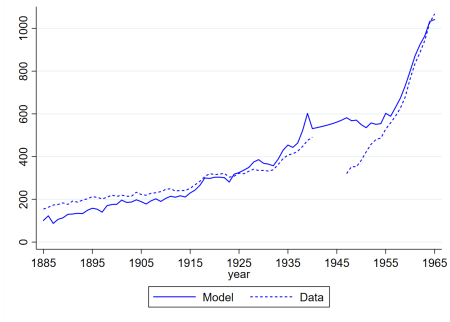
Before conducting a counterfactual simulation, to understand how much the model fits with the data, I plotted various economic indicators as shown in Figure 11. Figure 11 (a) shows the Gross National Product (GNP) per worker where the solid line is the model prediction and the dashed line is the actual data. The other panels show the share of the agricultural sector in the economy in terms of (b) GNP, (c) labor, (d) capital, and (e) consumption expenditure per worker. Overall, the model predicts the data well, and clearly shows the pattern during structural transformation: the share of agriculture in the economy decreases over time (Herrendorf et al., 2014).[45]

Next, I conducted counterfactual simulations by assuming a scenario in which the prewar production wedges continue to exist in the postwar period. To do so, I first assumed that capital moves freely between sectors so that the mobility component of the wedges for capital can be ignored. Then, further decomposing the production component of wedges yielded

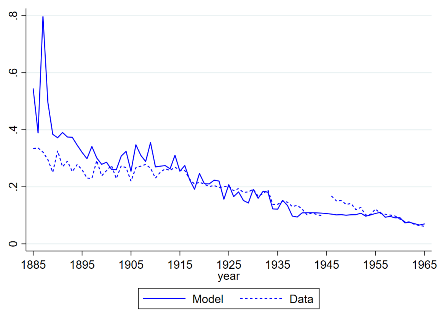
$$\tau_{PK} = \frac{MPK_{nt}}{p_t MPK_{at}} =: \frac{\tau_{PKn}}{\tau_{PKa}} \tag{18}$$

[44] A temporary jump of the consumption component in the 1880s was due to a sudden reduction in agricultural production caused by storms.

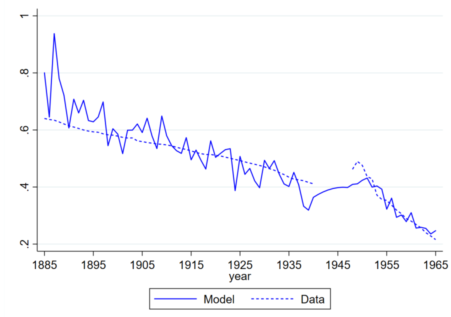
[45] By contrast, manufacturing was still increasing, and was not hump-shaped, in Japan during the study period.



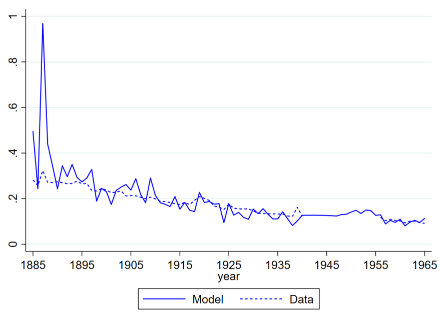
(a) GNP per worker



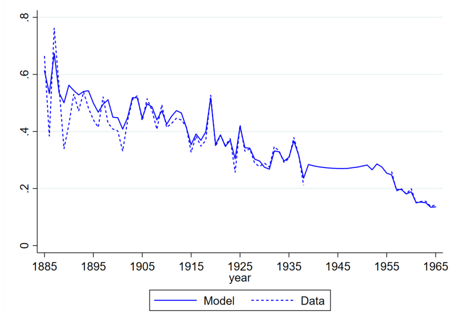
(b) Share of agricultural GNP



(c) Share of agricultural labor



(d) Share of agricultural capital



(e) Share of agricultural consumption expenditure per worker

Figure 11: Model Fit According to Various Economic Indicators

and

$$\tau_{PL} = \frac{MPL_{nt}/w_{nt}}{p_t MPL_{at}/w_{at}} =: \frac{\tau_{PLn}}{\tau_{PLa}}, \tag{19}$$

where τ_{PKn} and τ_{PKa} are the components of the capital wedge in non-agriculture and agriculture, respectively, and τ_{PLn} and τ_{PLa} are the components of the labor wedge in non-agriculture and agriculture, respectively.

Then, I fixed each of these components at the values in 1939 and conducted counterfactual simulations. Fixing τ_{PKa} and τ_{PKn} means that the postwar economy continues to have the same inefficiency for using capital in agriculture and non-agriculture, respectively, as in the prewar period. Similarly, fixing τ_{PLn} and τ_{PLa} means that the postwar economy still has the same inefficiency in hiring labor in non-agriculture and agriculture, respectively, as in the prewar period. In the following analysis, I quantify the effect of each of these changes on postwar economic growth.

The main components of interest are τ_{PKa} and τ_{PLn} because, as seen in the empirical section,

	GNP per worker	
	(1947-1965)	(1965)
	(1)	(2)
τ_{PK}	−0.002	−0.006
(τ_{PKa})	−0.009	−0.010
(τ_{PKn})	0.008	0.004
τ_{PL}	−0.121	−0.124
(τ_{PLa})	0.127	0.149
(τ_{PLn})	−0.378	−0.453
τ_{PK}, τ_{PL}	−0.160	−0.132

Notes: Each wedge is fixed at the 1939 level. Column (1) is the average of the percent change of GNP per worker relative to the actual data between 1947 and 1965. Column (2) is the percent change of GNP per worker relative to the data in 1965.

Table 10: Counterfactual Simulations, 1947-1965

the mechanization of agriculture progressed rapidly after land reform, which must be highly related with a change in τ_{PKa}. This in turn reallocated the young population from agriculture to non-agriculture, which must be highly related with a change in τ_{PLn}.[46]

Table 10 summarizes the simulation results. First, fixing all the production components at the prewar level would have decreased GNP per worker by 16% on average between 1947-65, and by 13.2% in 1965 only.[47]

Second, decomposing the effect provides additional insights into the forces behind structural transformation. The table shows that fixing τ_{PKa} and τ_{PLn} yields negative signs, indicating that the mechanisms described throughout this paper—i.e., agricultural mechanization (the reallocation of capital from urban regions to rural ones) and outmigration (the reallocation of labor from rural regions to urban ones)—seem to be the main drivers of postwar economic growth. By contrast, τ_{PKn} and τ_{PLa} give the opposite sign.

The mechanism can be described as follows. Both τ_{PLa} and τ_{PLn} were decreasing in the postwar period if they were not fixed. By fixing τ_{PLn}, the effect of τ_{PLa} dominates, and more labor would be employed in the agricultural sector such that the marginal products of labor (i.e., the component of τ_{PLa}) in agriculture would decrease. This affects the overall economy negatively. By contrast, fixing τ_{PLa} works in the opposite direction: more labor would be employed in the non-agricultural sector such that the marginal products of labor in non-agriculture (i.e., the component of τ_{PLn}) would decrease. In this case, fixing the prewar wedge would be beneficial for the economy.

By contrast, τ_{PKn} was increasing whereas τ_{PKa} was decreasing in the postwar period. By fixing τ_{PKa}, the first effect dominates and more capital would be used in the non-agriculture sector such that the marginal products of capital in the non-agriculture sector (i.e., the com-

[46] This presumes that the non-agricultural sector has the capacity to absorb these migrants, as argued in, e.g., Colmer (2021).

[47] The magnitudes are similar to those in Esteban-Pretel and Sawada (2014), who show a result consistent with Hayashi and Prescott (2008)—namely, the former authors found that fixing the share of employment in a simulated model of agriculture in the postwar period reduced the output by nearly 18%.

ponent of τ_{PKn}) would decrease. By contrast, fixing τ_{PKn} means that more capital would be used in the agriculture sector, which in turn would push more labor out of agriculture due to capital-labor substitution, thereby benefiting the overall economy.

The effect of fixing τ_{PKa} alone explains the reduction of GNP per worker by 1% per annum. This is a pure effect of the changes in the agricultural component of the capital wedge. According to a simple back-of-envelope calculation, this is equivalent to an increase in GNP of 327 billion yen for the year 1965 alone. This amount is very close to the total government expenditures during land reform, as mentioned in the Introduction. Therefore, the impact of the reallocation was considerable.

8 Conclusion

This paper studies the role of property rights, especially land ownership, in structural transformation from both micro and macro perspectives using Japan as a testing ground.

A rapid change occurred in the country in the postwar period, in which more capital, including advanced technologies, was absorbed by the agricultural sector and more labor was absorbed by the non-agricultural sector. As a factor limiting these movements, I studied the role of property rights, especially land ownership, using two natural experiments, i.e., a massive land reform and the introduction of low-cost agricultural technologies.

Generating a unique dataset by digitizing various paper-based sources, I showed that land ownership increased the adoption of the new low-cost agricultural technologies and increased the outmigration of young people from rural areas to urban centers when the low-cost technologies became available. The effects tended to be larger in areas where there was more access to credit and where the farm size was larger. A quantitative exercise using a two-sector neoclassical growth model also indicated that the impact of the factor reallocation was considerable.

Although the paper provides some insights for economic development, the external validity of the findings should be tested in other settings. For example, it would be interesting to test them in developing countries today including Africa, where the manufacturing sector tends to be small and informal (McMillan and Zeufack, 2022). Agricultural policies may need to be complemented with policies that would promote non-agricultural sectors. This is left for future research.

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Online Appendix for *Tillers of Prosperity: Land Ownership, Reallocation, and Structural Transformation*

Shuhei Kitamura*

Abstract

This Online Appendix includes the text, tables, and figures that have been excluded from the main text owing to space constraints.

A.1 Data Sources and Variables

Land reform data

The data of land reform are from *Nochi Kaikaku Siryo Shusei (The Collection of Agricultural Land Reform Materials)* (Nochi Kaikaku Shiryo Hensan Iinkai, 1980). Using the data source, I constructed the following variables:

- *Owned and tenanted farmlands*. I calculated an owner share variable by dividing the area of owned farmlands by the total area of farmlands. I also used the area of tenanted farmlands before land reform as a control variable, for which I took the natural logarithm.
- *Pre-reform farmland sizes*. I devised a variable representing the pre-reform average farmland size by dividing the area of farmlands before land reform by the number of individuals who work in the agricultural sector, with the latter number taken from the census (see below). The pre-reform farmland size is used as a control variable.

Other agricultural data

Most of the agriculture-related variables were taken from the Agricultural Censuses for 1950, 1955, 1960, and 1965 (Norinsho, 1950, 1959b, 1960, 1965). For agricultural income, I digitized the Statistics of Agricultural Income (Norinsho, 1962, 1968). Finally, the data on agricultural cooperatives were taken from Norinsho (1959a).

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Using these sources, each variable was constructed as follows:

- *Agricultural population.* I constructed the variable representing the share of the agricultural population by dividing the agricultural population by the total population; the latter number was taken from the census (see below) in 1950.

- *Agricultural machines.* Because the 1960 and 1965 census reported private and communal power tillers separately, I aggregated these numbers to make the values consistent with other years. I divided the number of power tillers by the number of farm households in each year to measure the penetration of the machines into agricultural communities. This variable is used as one of the main dependent variables.

- *Migration.* Migration-related variables were taken from the 1960 agricultural census, because such information was only available in that census. The 1960 agricultural census records the number of farm household members who had outmigrated by February 1, 1960, for different categories.

- *Paddy fields.* The share of paddy fields was determined by dividing the area of paddy fields in 1950 by the total area of each municipality, which was computed using the shapefiles of municipal boundaries (see below), and by taking the natural logarithm.

- *Livestock.* I calculated the share of farm households that had used livestock in production by dividing the number of such farm households by the total number of farm households in 1950. Since this variable sometimes took a value of zero, I added 0.01 and took the natural logarithm.

- *Average farm sizes.* I first computed the area of farmlands in each "bin" of land area ((a) less than 3 are, (b) 3 to 5 are, (c) 5 are to 1 hectare, etc.) defined in the censuses, by multiplying the number of farm households in each bin by the smallest land size in each bin (0.01 for (a), 0.3 for (b), 0.5 for (c), etc.). Then, I aggregated these numbers to compute the total land area, and divided this value by the number of farm households.

- *Agricultural income.* For the variable on agricultural income, I multiplied the gross revenue of agricultural production by the agricultural income rate. Although the gross revenue of agricultural production was available for each municipality, the agricultural income rate was available only at the level of the agricultural region, a set of municipalities within a prefecture but smaller than that prefecture. The numbers of regions were 305 and 151 in the 1960 and 1965 Statistics of Agricultural Income, respectively.

- *Agricultural cooperatives.* The members of agricultural cooperatives were counted at the level of the agricultural district, which is smaller than a municipality. To determine the share of the membership of the agricultural cooperatives, these numbers were aggregated at the municipality level and divided by the agricultural population.

- *Education*. Education-related variables were taken from the 1960 agricultural census, as such information was only available in that census. The 1960 agricultural census recorded the number of farm household members who were studying in high school or a higher educational institution at the time of the census, for different categories.

Demographic data

Demographic data were taken from the national censuses of 1930, 1950, 1960, and 1965 (Yamamoto and Kishimoto, 2006; Takita et al., 2012; Sato and Kishimoto, 2014). I also consulted the Vital Statistics in 1947 to measure births before land reform (Department of Statistics and Investigation, 1949).

Using these sources, I constructed the following variables:

- *Population*. I computed the share of the population aged 15-19 by dividing the population of that age group by the total population. This variable is used as one of the main dependent variables. I also used the population in 1950 as a control variable for which I took the natural logarithm. The 1950 population was also used to determine the share of the agricultural population (see above).
- *Agricultural employment*. The number of individuals who work in the agricultural sector was used to determine the variable on pre-reform farmland sizes (see above).
- *Births*. I took the natural logarithm of the number of births in 1947.

GIS data

Elevation data were taken from the Shuttle Radar Topography Mission (SRTM3) of the National Aeronautics and Space Administration (NASA). Agricultural suitability data were taken from the Global Agro-Ecological Zones (GAEZ) data of the FAO. Finally, the locations of train stations were taken from the National Land Numerical Information of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

Using such data sources, the following variables were constructed:

- *Terrain*. I computed the mean slope and mean elevation using ArcGIS's `Zonal Statistics as Table` (in addition to `Slope` for computing the slope) and took the natural logarithm. Since the elevation variable contained negative values, I normalized it by subtracting the lowest elevation and then added 0.01 before taking the logarithm.
- *Agricultural suitability*. I used the crop suitability index for wet rice because rice is the most common agricultural crop in Japan. I first used ArcGIS's `Zonal Statistics as Table` to compute the municipal average of the agricultural suitability index for the high- and low-input level,

respectively, and then subtracted the latter from the former to capture the difference in the crop suitability.[1] The resulting variable captures the suitability (profitability) for adopting new technologies (Bustos et al., 2016). Since the cell size of the original data (0.5-degrees by 0.5-degrees) was too big for some small municipalities, I resized these cells using ArcGIS's `Resample` before computing the statistics.

- *Distance to the nearest transportation.* As a variable on distance to the nearest public transportation, I computed the distance to the nearest train station from each municipality. Trains were the most common mode of transportation during the period studied, especially for distant trips like those considered in this paper. There were 12,951 stations spread across the country, both inland and along coastlines. I used the stations that existed in 1965, because the unit of analysis was the 1965 municipality. I used ArcGIS's `Near` to compute distance between the centroid of a municipality polygon and the nearest train station, and took the natural logarithm.

- *Distance to the nearest metropolitan area.* Using a similar approach as for the above variable, I used ArcGIS's `Near` to compute the distance between the centroid of each municipality polygon and the nearest prefectural government in three metropolitan areas (Tokyo, Osaka, and Nagoya), and took the natural logarithm. The Tokyo metropolitan area included Tokyo, Kanagawa, Chiba, and Saitama Prefectures; the Osaka metropolitan area included Osaka, Hyogo, Kyoto, and Nara Prefectures; the Nagoya metropolitan area included Aichi, Mie, and Gifu Prefectures.

A.2 Tables and Figures

[1] The high-input level assumes that the production is fully mechanized and improved varieties are used, while the low-input level assumes a subsistence-based farming system with labor-intensive production.

Table A.1: Effects of Land Ownership on Local Demographics: Additional Controls

	Dependent variable: Population share aged 15-19								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Owner share × Post	−0.023	−0.020	−0.023	−0.022	−0.022	−0.019	−0.019	−0.018	−0.018
	(0.008)	(0.008)	(0.006)	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.006)
Municipality controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Population	Births	Paddy field	Topography	Ag. suit.	Livestock	Dist. metro.	Dist. trans.	All
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture-by-year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control mean (1950)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
R^2	0.63	0.64	0.67	0.65	0.64	0.64	0.64	0.65	0.68
Observations	8396	8312	8396	8396	8396	8396	8396	8396	8312

Notes: Standard errors are clustered at the prefecture level. The dependent variable is the share of the population aged 15-19. The additional controls are population (Column (1)), the number of births (Column (2)), the share of paddy fields (Column (3)), elevation and slope (Column (4)), agricultural suitability (Column (5)), the share of farm households using livestock (Column (6)), distance to the nearest metropolitan area (Column (7)), distance to the nearest transportation (Column (8)), and all of them (Column (9)), all interacted with year dummies.

Table A.2: Effects of Land Ownership on Technology Adoption: Additional Controls

	Dependent variable: Power tillers per farm household								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Owner share × Post	0.119	0.099	0.104	0.099	0.106	0.114	0.111	0.110	0.098
	(0.023)	(0.022)	(0.022)	(0.023)	(0.022)	(0.024)	(0.024)	(0.023)	(0.023)
Municipality controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Population	Births	Paddy field	Topography	Ag. suit.	Livestock	Dist. metro.	Dist. trans.	All
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture-by-year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control mean (1950)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
R^2	0.50	0.49	0.49	0.50	0.49	0.48	0.48	0.49	0.51
Observations	11175	11063	11175	11175	11175	11175	11175	11175	11063

Notes: Standard errors are clustered at the prefecture level. The dependent variable is power tillers per farm household. The additional pre-treatment municipality controls are population (Column (1)), the number of births (Column (2)), the share of paddy fields (Column (3)), elevation and slope (Column (4)), agricultural suitability (Column (5)), the share of farm households using livestock (Column (6)), distance to the nearest metropolitan area (Column (7)), distance to the nearest transportation (Column (8)), and all of them (Column (9)), interacted with year dummies.

Table A.3: Effects of Land Ownership on Local Demographics Technology Adoption: Drop Regions

	Dependent variable:					
	Pop. share aged 15-19			Power tillers per farm hh.		
	(1)	(2)	(3)	(4)	(5)	(6)
Owner share × Post	−0.018	−0.020	−0.022	0.098	0.075	0.089
	(0.006)	(0.006)	(0.007)	(0.023)	(0.023)	(0.022)
Municipality controls	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Municipality F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture-by-year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Dropped	None	Hokkaido	Hokkaido & Tohoku	None	Hokkaido	Hokkaido & Tohoku
Control mean (1950)	0.10	0.10	0.10	0.01	0.01	0.01
R^2	0.68	0.69	0.66	0.51	0.51	0.49
Observations	8312	7862	6776	11063	10463	9015

Notes: Standard errors are clustered at the prefecture level. Columns (1) and (4) are the same as Column (9) in Tables A.1 and A.2, respectively. Columns (2) and (5) exclude municipalities in Hokkaido Prefecture, and Column (3) and (6) exclude municipalities in Hokkaido Prefecture and those in the Tohoku region, i.e., Aomori, Iwate, Miyagi, Yamagata, and Fukushima Prefectures. Control variables are the same as in Column (9) in Tables A.1 and A.2.

Table A.4: Effects of Land Ownership on Local Demographics and Technology Adoption: Drop Top and Bottom Percentiles of Owner Share

	Dependent variable:							
	Population share aged 15-19				Power tillers per farm household			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Owner share × Post	−0.018	−0.024	−0.021	−0.027	0.098	0.109	0.120	0.141
	(0.006)	(0.008)	(0.010)	(0.012)	(0.023)	(0.036)	(0.035)	(0.038)
Municipality controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture-by-year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dropped percentiles	None	1 & 99	5 & 95	10 & 90	None	1 & 99	5 & 95	10 & 90
Control mean (1950)	0.10	0.10	0.10	0.10	0.01	0.01	0.00	0.00
R^2	0.68	0.68	0.70	0.71	0.51	0.51	0.52	0.53
Observations	8312	8141	7492	6670	11063	10836	9971	8877

Notes: Standard errors are clustered at the prefecture level. The dependent variable for Columns (1)-(4) is the share of the population aged 15-19 and for Columns (5)-(8) is power tillers per farm household. Columns (1) and (5) are the same as Column (9) in Tables A.1 and A.2, respectively. Columns (2) and (6) drop the 1st and 99th percentiles, Columns (3) and (7) drop the 5th and 95th percentiles, and Columns (4) and (8) drop the 10th and 90th percentiles of owner share. Control variables are the same as in Column (9) in Tables A.1 and A.2.

Table A.5: Effects of Land Ownership on Local Demographics and Technology Adoption by Quantile

	Dependent variable:			
	Pop. share aged 15-19		Power till. per farm hh.	
	(1)	(2)	(3)	(4)
Owner Share (Q2) × Post	0.001	0.001	0.007	0.006
	(0.001)	(0.001)	(0.003)	(0.003)
Owner Share (Q3) × Post	−0.001	−0.001	0.011	0.007
	(0.001)	(0.001)	(0.004)	(0.004)
Owner Share (Q4) × Post	−0.003	−0.003	0.017	0.012
	(0.001)	(0.001)	(0.004)	(0.004)
Municipality controls	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
Municipality F.E.	Yes	Yes	Yes	Yes
Dropped	None	Hokkaido	None	Hokkaido
Control mean (1950)	0.10	0.10	0.01	0.01
R^2	0.68	0.69	0.51	0.51
Observations	8312	7862	11063	10463

Notes: Standard errors are clustered at the prefecture level. The dependent variable for Columns (1) and (2) is the population aged 15-19 and for Columns (3) and (4) is power tillers per farm household. Control variables are the same as in Column (9) in Tables A.1 and A.2. Columns (2) and (4) exclude municipalities in Hokkaido Prefecture. The baseline is "Owner share (Q1) × Post".

Table A.6: Effects of Land Ownership on Technology Adoption: Poisson Pseudo-likelihood Regression

	Dependent variable:	
	Power till. per farm hh.	
	(1)	(2)
Owner share × Post	2.396	1.859
	(0.602)	(0.485)
Municipality controls	Yes	Yes
Additional controls	Yes	Yes
Year F.E.	Yes	Yes
Municipality F.E.	Yes	Yes
Control mean (1950)	0.01	0.01
Pseudo R^2	0.17	0.20
Observations	11175	11063

Notes: Standard errors are clustered at the prefecture level. The dependent variable is power tillers per farm household. Control variables are the same as in Column (9) in Table A.2. I used `ppmlhdfe` command in STATA (Correia et al., 2019).

Table A.7: Balance Check for Adjacent Municipality Pairs Using Cross-Sectional Data

	Dependent variable:								
	Population	Births	Paddy fields	Slope	Elevation	Ag. suit.	Livestock	Dist. metro.	Dist. trans.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Owner share	38926.840	1226.783	58.849	−4.271	−0.004	0.123	0.036	3.581	0.748
	(28720.143)	(790.327)	(168.692)	(7.506)	(0.051)	(0.076)	(0.261)	(8.394)	(4.573)
Municipality controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Twin F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dependent variable mean	24173.81	770.80	462.67	25.56	0.03	0.15	0.32	177.30	6.70
R^2	0.84	0.82	0.96	0.95	0.96	0.93	0.75	1.00	0.83
Observations	1745	1723	1745	1745	1745	1745	1745	1745	1745

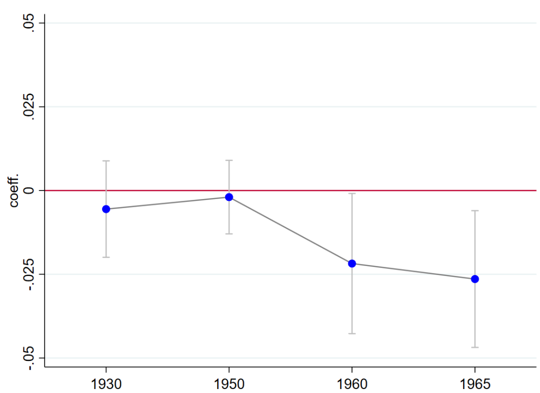
Notes: Standard errors are clustered at the municipality pair level. The dependent variable is population (Column (1)), the number of births (Column (2)), the share of paddy fields (Column (3)), elevation (Column (4)), slope (Column (5)), agricultural suitability (Column (6)), the share of farm households using livestock (Column (7)), distance to the nearest metropolitan area (Column (8)), and distance to the nearest transportation (Column (9)). The baseline municipality controls are the average size of farmlands, the total area of tenanted farmlands, and the share of the agricultural population.

Table A.8: Effects of Land Ownership on Agricultural Income per Farm Household

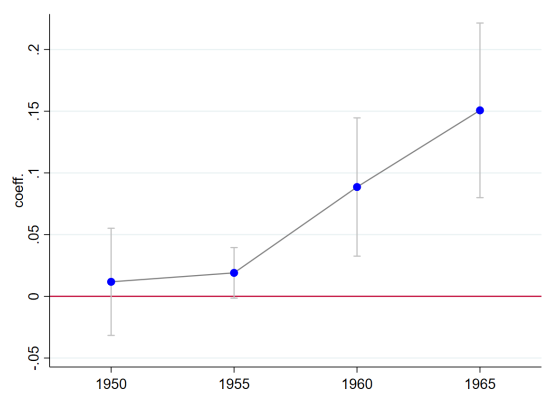
	Dep. variable: Agricultural income		
	1960	1965	Difference
	(1)	(2)	(3)
Owner share	0.182	0.301	0.115
	(0.056)	(0.092)	(0.042)
Municipality controls	Yes	Yes	Yes
Prefecture F.E.	Yes	Yes	Yes
Dependent variable mean	0.19	0.30	0.11
R^2	0.64	0.65	0.43
Observations	2742	2763	2735

Notes: Standard errors are clustered at the prefecture level. The dependent variables are agricultural income per farm household in 1960 (Column (1)) and 1965 (Column (2)), and the difference in agricultural income per farm household between these years (Column (3)). The pre-treatment municipality controls are the same as in Table 4 in the main text.

Figure A.1: Estimated Coefficients by Year (without Additional Controls)



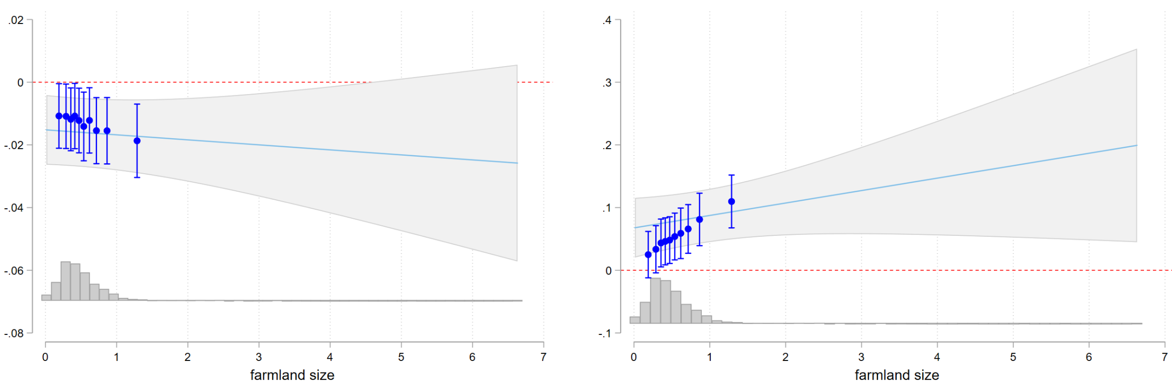
(a) Population share 15-19 years old



(b) Power tillers per farm household

Notes: The dependent variable in the left panel is the share of the population aged 15-19, and that in the right panel is power tillers per farm household. Control variables are the same as in Columns (4) and (9) in Table 2 in the main text without municipality fixed effects.

Figure A.2: Heterogeneous Effects by Farm Size including Hokkaido Prefecture



(a) Population share 15-19 years old

(b) Power tillers per farm household

Notes: The dependent variable in the left panel is the share of the population aged 15-19, and that in the right panel is power tillers per farm household. Control variables are the same as in Columns (5) and (10) in Table 2 in the main text. To make the figures, I used the "binning estimator" (Hainmueller et al., 2019), in which the average farmland size is divided into ten bins using percentiles.

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