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"The Impact of Farmland Readjustment and Consolidation on Structural Adjustment: The Case of Niigata, Japan"

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The impact of farmland readjustment and consolidation on structural adjustment: The case of Niigata, Japan

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Abstract

Improving agricultural productivity is a pressing challenge for rapidly growing economies. Farmland concentration among core famers is instrumental for reaping the economies of scale. However, farmland fragmentation often serves as a barrier to such structural adjustments. This paper studies Farmland Improvement Projects in Japan, which physically mitigate farmland fragmentation by merging and enlarging small plots and consolidating land parcels among farmers. I employ community-level panel data to make use of difference-in-differences matching estimators, in order to measure the projects' impacts. I find positive effects of the projects on structural adjustment, in the form of machinery-work outsourcing.

Keywords: farmland improvement project; farmland concentration; farmland fragmentation; structural adjustment; Japan

JEL classifications: Q15; Q18

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1. Introduction

In becoming more economically industrialized, many countries experience a transition in the agricultural sector. A common observation is the migration of the rural population into urban areas. This change in the labor market usually accompanies a concentration of farmland among farmers who remain in the rural areas, from those who migrated. Consequently, in the midst of such transitions, we observe a decline in the total number of farms and an increase in the average operational farm size[1]. This structural adjustment is imperative for improving the efficiency of the agricultural sector, as it reduces inflating labor costs due to rising wages and also leads to benefits that arise from economies of scale, largely through the efficient use of agricultural machinery[2]. Stagnation in farmland concentration implies the retention of inefficient farms and thus a loss of competitiveness in the agricultural sector.

While the success of structural adjustment depends primarily on how land markets function[3], this study focuses on farmland fragmentation, a common yet unstudied obstacle that prevents smooth land reallocation. Farmland fragmentation is a phenomenon in which farmers operate many small, dispersed plots. Although farmland fragmentation could offer benefits in terms of reducing risk through the spatial dispersion of plots (Blarel et al. 1992), it comes at the cost of increasing the number of work hours and travelling costs involved in moving among the plots; it also inhibits the efficient use of agricultural machinery[4]. Moreover, farmland fragmentation restricts farmland transactions, as it is difficult for farmers to expand farm size without exacerbating parcel dispersion,[5] otherwise by finding suitable plots that are adjacent to those they already own. Such a phenomenon is commonly observed in Asia (e.g., China, Japan, India, Taiwan, and Vietnam), where small-scale farming persists, and in Central and East Europe, where the ownership of nationalized farmland has been dispersed through land reforms to numerous

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[1] Eastwood, Lipton, and Newell (2010) find a positive association between mean farm size and GDP.

[2] Note that the implications of farmland concentration differ at different stages of economic development. Farmland concentration could be harmful in developing economies where many rural people lack access to land and when scales of economy from mechanization are not yet present.

[3] For literature on the functioning of land markets, see Deininger (2003) and Otsuka (2007).

[4] Inefficiencies caused by farmland fragmentation have been reported in many countries, such as Bangladesh (Rahman and Rahman 2008), Rwanda (Bizimana, Nieuwoudt, and Ferrer 2004), Vietnam (Hung, MacAulay, and Marsh 2007), China (Chen, Huffman, and Rozelle 2009; Nguyen, Cheng, and Findlay 1996; Wan and Cheung 2001), Jordan (Jabarn and Epplin 1994), and Japan (Kawasaki 2010).

[5] In this study, I define a *parcel* as a block or complex of one or more contiguous plots.

family farms[6]. These countries therefore face the potential risk of farmland fragmentation, and the attendant induced stagnation of structural adjustment could hamper the growth of agriculture and industrialization.

This study examines the case of Japan, which has been suffering from both stagnation vis-à-vis structural adjustment and farmland fragmentation. The necessity of structural adjustment to improve agricultural productivity via the exertion of economies from scale has been recognized since the late 1950s. However, progress in Japan has been slow, and the mean farm size per farm household there has remained small (i.e., 1.30 ha in 2005)—at most, one-hundredth the size of that in the United States. While there are a number of institutional and cultural reasons behind the stagnation of farmland reallocation in Japan, farmland fragmentation has continued to be the major land-policy issue. The struggling experience of Japan thus provides important lessons for rapidly growing economies—especially in Asia, which faces similar agro-economic land conditions.

To address this situation, the Japanese government has been implementing Farmland Improvement Projects (FIPs). Such projects involve *farmland readjustment*, in which several small plots are physically merged and reshaped into one large plot, and *farmland consolidation*[7], which amalgamates the previously dispersed parcels of each farm household through plot exchanges among farmers. Existing studies have found that FIPs have had a positive effect on farm management, through the reduction of production costs (Kondo 1998; Kiminami and Kiminami 2005). It has also been reported that FIPs facilitate rental and farmland concentration (Kunimitsu 2008; Takeya 1986; Takahashi 2010). Through its own evaluation, the Ministry of Agriculture, Forestry, and Fisheries (MAFF) (2005b) asserts that FIPs have contributed to the prevention of farmland abandonment, improved labor and land productivity, expanded farm size, reduced production cost, and concentrated farmland among core farmers. These studies, however, tend to be anecdotal or descriptive, and the analyses therein are prone to confounding factors that affect structural adjustment and the possibility of endogenous project placement.

In this study, I estimate the impact of FIPs on structural adjustment and farmland use in Niigata prefecture. I use community-level panel data drawn from the Agricultural Census, and employ first-difference, difference-in-differences (DID), and (propensity score) matching

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[6] Some studies of farmland fragmentation include those of Heston and Kumar (1983), Kawasaki (2010), Niroula and Thapa (2005), Ram, Tsunekawa, Sahad, and Miyazaki (1999), Sikor, Muller, and Stahl (2009), and Tan, Heernik, and Qu (2006).

[7] I explicitly distinguish the concepts of *farmland concentration* and *farmland consolidation* in the following way. Farmland concentration involves the reallocation of farmland among farm households towards fewer core farmers, and it relates to structural adjustment. On the other hand, farmland concentration involves the reallocation of farmland within each farm household to gather dispersed plots into fewer parcels, and it relates to farmland fragmentation.

strategies to estimate impacts. I find that the implementation of an FIP in a community roughly doubles the proportion of paddies that outsource some core machinery tasks (e.g., plowing, planting, and harvesting). Outsourcing is one form of farmland concentration among operators at the operational level; by outsourcing their agricultural machinery, farmers can reduce production costs by eliminating operation, maintenance, and renewal costs. FIPs also tend to facilitate farmland rental, but estimates are not always precise. I also found that FIPs help keep farmers in the agricultural sector. Thus, FIPs seem to have promoted structural adjustments in the form of outsourcing without reducing the number of farmers, rather than facilitating farmland concentration through exit and reallocation. I discuss within this paper the implications of the different modes of structural adjustment.

The rest of this paper is organized as follows. Section 2 discusses the context of analysis in Japanese agriculture, with a focus on trends vis-à-vis structural adjustment, farmland fragmentation, and FIPs. Section 3 presents data and discusses this study's measurement methodology. The impacts that FIPs have had on structural adjustment are presented in Section 4. Section 5 discusses the mechanism and modes of structural adjustment by examining the effects of FIPs vis-à-vis the deterioration of agricultural labor. Section 6 provides concluding remarks.

2. Context and institutional background

2.1. Concept and modes of structural adjustment

I define "structural adjustment" in agriculture as the reallocation of resources to reduce costs, increase productivity, and gain international competitiveness under a free trade regime. One typical manifestation of structural adjustment is farmland concentration. The process begins with a deterioration of agricultural labor due to a lag of growth in productivity, which is associated with a low wage rate compared to the non-agricultural sector. The outflow of agricultural labor increases the supply of farmland. When the reallocation of the released farmlands among farm households is successful, the process completes with farmland concentration and an increase in the average size of operational farms. Otherwise, farmlands would be abandoned.

The primary channels by which these released farmlands are reallocated are through purchase or rental, causing a concentration of farmland in terms of ownership or management. In the Japanese context, outsourcing serves as a third channel. Outsourcing is a form of labor division where farmers conduct daily management and care—e.g., the control of water, application of fertilizer, and weeding—while outsourcing to core operators heavy seasonal machinery operations such as plowing, planting, and harvesting. I consider outsourcing a mode of structural adjustment, since it essentially serves to concentrate farmland use among operators at the operational (i.e., task) level and helps reduce production cost by eliminating the maintenance cost of their agricultural machinery[8].

[8] Fujiki (1999) compares Japan with Taiwan in this respect and shows that Taiwanese agriculture

2.2. Structural adjustment in Japan[9]

Japan's rapid economic growth started in the mid-1950s and soon widened disparities in productivity and income between its agricultural and non-agricultural sectors, triggering the outflow of agricultural labor. The Japanese government intended to narrow income disparity by making structural adjustments in the agricultural sector. The expectation was that the outflow of agricultural labor would proceed from the closing-down of farm households, and that the farmlands would then be released and reallocated. In reality, until the mid-1970s, many farmers did not quit farming, but instead became part-time farmers; they successfully shifted their households' labor to the non-agricultural sector without releasing farmland, largely by commuting to urban cities on weekdays and managing their farmlands on weekends and holidays.

Figure 1 depicts Japanese trends in agricultural labor, from 1955 to 2000. The decline in the number of farm households and farmers (i.e., the population mainly engaged in farming)—which declined during this period by 67.1% and 76.9%, respectively—indicates a clear and quantitative deterioration of agricultural labor. Note that the decline in the number of farmers occurred much more rapidly than the decline in the number of farm households; this implies that farm households have tended to keep their farmlands and to continue farming, albeit with fewer family members. Even among those who continued to farm, the *qualitative* deterioration in terms of aging and part-time farming is apparent. The percentage of elderly farmers (i.e., those older than 60 years) has nearly tripled; in 2005, 70.1% of the farmers were older than 60 years and 78.2% of the farm households were farming part-time[10].

The MAFF has put substantial effort into the facilitation of farmland reallocation through purchase and rental, largely by relaxing institutional barriers that hinder farmland transactions. However, the average operation size for commercial farm households has increased only minutely, from 1.05 ha in 1985 to 1.30 ha in 2005[11]. In 1993, the government established the Agricultural Management Basis Improvement Law (AMBIL), which identifies *core farmers*[12]; it concentrates policy support and accelerates the concentration of farmland to that group of farmers. Through

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maintained efficiency through "custom farming," in which agricultural machinery is shared and farmers entrust one another with machinery work.

[9] For brief, English-language summaries of agriculture in Japan, see Hayami and Kawagoe (1989), OECD (2009), and Yamashita (2006).

[10] The decline in the ratio of part-time farmers to all farmers was due to aging: those who used to farm part-time started to retire from their regular, non-agricultural sector work and thus became full-time, elderly farmers.

[11] Excluding Hokkaido, based on MAFF (2007).

[12] *Core farmers* are those "already or aiming to be an efficient and stable farm and are expected to lead the agricultural sector."

AMBIL, the share of farmland operated by core farmers increased from 20% in 1996 to 42% in 2006; nonetheless, the pace of farmland concentration has been unsatisfactory (MAFF 2008)[13].

The deterioration of agricultural labor and the stagnation of farmland concentration together imply that some of the released farmlands have been left unmanaged. Indeed, the area of abandoned farmland has increased; in 2005, it comprised approximately 10% (386,000 ha) of all farmland. This situation is exacerbating social concerns with regard to food security, and so the prevention of farmland abandonment has become a major goal of agricultural policy.

2.3. Farmland fragmentation and farmland improvement projects

Why is structural adjustment in Japan stagnant? On the supply side, it is often said that farmers tend to hold their farmland and wait for opportunities to sell it to developers, as converting it to housing or commercial purposes offers a higher selling price. Also, many farmers have emotional or sentimental attachments to plots inherited from ancestors, and thus hesitate to release their farmlands[14]. On the demand side, MAFF (2008) reports that the two most frequently cited reasons for the stagnation of farmland concentration are the instability of farm income and the prices of agricultural products, implying that even core farmers cannot risk farm-size expansions.

In this study, I focus on the third most frequently cited reason: farmland fragmentation. MAFF (2008) reports the survey result that although core farmers tend to have larger farm sizes, their plots are typically small and dispersed: the average operation size of the 203 sampled core farmers was 14.8 ha, but their plots were dispersed over, on average, 28.5 separate parcels. The dispersion of parcels increases the number of work hours needed to move among the parcels, and the smallness of the plots hinders the efficient use of agricultural machinery; these are the major causes of low productivity in Japanese agriculture (Kawasaki 2010, 2011). The unprofitability of agriculture has led to a decline in the number of farm households and a general lack of core farmers. The key issue is that farmland concentration (and an increase in mean farm size) is actually not sufficient; the parcels need to be concentrated contiguously.

To address this situation, the Japanese government has been implementing FIPs[15], which improve production conditions by developing infrastructure pertaining to irrigation, drainage, and roads, and by facilitating farmland readjustments that physically merge and reshape several small plots into larger plots (**figure 2**). After farmland is readjusted, farmers can negotiate with regard to which new plots they will take. Throughout the reallocation process, for each farmer,

[13] In 2005, the MAFF established its vision, that 70–80% of the farmland would be concentrated among core farmers by 2015.

[14] This kind of emotional sentiment is also reported in Nepal (Thapa and Niroula 2008) and Central Europe (van Dijk 2007).

[15] For a brief overview of FIPs in Japan, see Nakashima (2005).

previously dispersed plots are consolidated into one or two parcels (i.e., farmland consolidation).

FIPs are implemented by the central government or prefectures based on requests from rural communities. Each project site must have a minimum coverage area of 20 ha. A project implementation can be forced by agreement among more than two-thirds of the landowners in the project area. Typically, half of each project's budget is funded by the government, 30% by prefectures, and the remainder by municipalities and farm households. Due to budgetary limitations, it is common for several years to pass before a project is initiated.

The primary objective of an FIP is to improve the productivity of individual farms. However, since the AMBIL in 1993, emphasis has shifted to structural adjustments: increasing farmland transactions, nurturing core farmers, and concentrating farmland among core farmers (MAFF 2005a). There are several reasons to expect that FIPs will enhance farmland concentration.

On the demand side, improvements in production conditions reduce production costs and likely stimulate the demand for farm-size expansion among core farmers. FIPs also make it much easier and less costly than is otherwise the case to expand farm size, because one need rent or purchase only one plot instead of many small plots to obtain the same aggregate size of farmland. This lowers the transaction costs associated with searching and negotiating with different landowners, and it also reduces the difficulties inherent in managing many dispersed parcels.

On the supply side, the physical transformation of plots due to farmland readjustment is said to ease farmers' emotional bonds or sentimental attachment to plots inherited from ancestors and lessen their hesitation to sell or rent them (Kunimitsu 2008). It is also indicated that FIPs mitigate asymmetric information on plots' soil conditions, because the readjustment physically shuffles and equalizes the soils among merged plots. Furthermore, FIP implementation encourages farmers to plan future operations and is likely to promote retirement, farmland rental, or outsourcing by elderly farmers and small, part-time farmers[16]. Finally, some FIPs require that a certain share of farmland must be concentrated among core farmers as a condition of the FIP implementation; this also boosts farmland rental and outsourcing.

3. Data and method

3.1. Data

I focus on the impact of FIPs in Niigata prefecture. Although Niigata is the second-largest rice-producing prefecture in Japan, the progress of FIPs there has been slow. A considerable number of FIPs have been implemented in recent years, to catch up with other areas. Between 1993 and 2001, Niigata increased its area of readjusted paddies by 14,751 ha—the highest among

[16] FIPs could bring about the opposite effect (i.e., suppress the supply of farmland), since improvements in production conditions would enable the continuation of cultivation by elderly farmers. Thus, it could affect both labor deterioration and structural adjustment. I discuss this issue in Section 5.

all prefectures for that period[17].

I use information from the *Rural Community Card, World Census of Agriculture and Forestry 2000* in this analysis. The unit of observation is the rural community—which, according to that Census, is the "smallest unit of regional society in rural villages." The data are constructed by aggregating household-level census data from the *Farm Household Survey* for farm households residing in each community. This is the most detailed and comprehensive data available for the purpose of the study. I emphasize three limitations therein. First, many variables on farmland area (owned, managed, rented-in, outsourcing) do not necessarily accord with the actual (area-basis) farmland area within the regional domain of each community. This is because the data are constructed on a farmer basis (i.e., by summing up the area data of farm households who reside in each community), and some farmers own or manage farmlands outside the resident community[18]. Second, the area of readjusted paddies used as the indicator of FIP implementation is on an area basis, and such numbers are derived from the *Rural Community Survey*[19]. Thus, I concede that the key variables come from different surveys, and that there may be some inconsistencies between the two. Third, I find some farmland area data of the *Rural Community Survey* inconsistent over time[20]. Therefore, I refrain from using the absolute area and instead use the *ratio* of area of paddies readjusted over the (total) area of paddies, expecting that the data are more consistent within each time point.

Table 1 reports the definitions and summary statistics of the variables used in the analysis. In 1990, on average, there were 23.7 farm households managing a total of 30.0 ha of paddies in one rural community. However, the figures show a clear deterioration of agricultural labor: during 1990–2000, the number of farm households declined by 20.3% (by 4.8 households) and the proportion of elderly farmers (those above 65 years old) increased by 58.4%, from 36.4% to 57.7%. These numbers are roughly on par with the national averages of the time[21].

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[17] However, in 2001, the proportion of area comprising readjusted paddies in Niigata was still 50.3%, which is still lower than the national average of 57.4%.

[18] Strictly speaking, "the area of farmland managed in a community" is "the area of farmland managed by farm households residing in that community." I report in Table 1 the area of paddies on an area basis. The mean area of paddies on an area basis is 32.6 ha, whereas the area of paddies managed on a farmer basis is 29.7 ha. The difference comes from management in and outside the resident community and the measurement error of the area-basis data.

[19] This Survey is one component of the *World Census of Agriculture and Forestry*, which interviews "prominent residents" in each community to gather information on that community's circumstances.

[20] I observe several large increase or decrease in the (area-basis) area of paddies, which is quite unlikely in the Japanese context.

[21] From 1990 to 2000, the number of farm households declined by 21.1%, and the proportion of

The question is whether the paddies that belonged to exiting farm households were successfully reallocated or managed by those who remained. The figure shows that the released paddies were reallocated through rental, rather than through purchase: the paddy area owned declined by 4.5 ha (16.6%), from 27.1 ha to 22.6 ha; meanwhile, the paddy area rented increased by 2.0 ha (54.0%). However, neither reallocation nor rental could help manage released farmland sufficiently. The paddy area managed declined by 2.5 ha (8.3%) and the abandoned farmland area increased by 0.09 ha (10.2%). On the other hand, the increasing areas of paddy accepting various agricultural work indicate that more paddies (presumably those owned by elderly farmers) were handled through outsourcing.

The primary indicator of FIP implementation in a community is the value of the variable %Readjusted, which is the ratio of the area of readjusted paddies to the total area of paddies. While this is a measure of farmland readjustment, it is usually combined with considerations of infrastructure development and farmland consolidation. Therefore, the measured impact reflects the composite effects of these project components. I also adopt a binary indicator of project implementation to compare the "treated" and "control" (i.e., untreated) communities. The variable is set to unity if the area of readjusted farmland increased *and* the ratio of readjusted farmland increased by 25 percentage points[22] between 1990 and 2000; otherwise, the variable is set to 0.

The outcomes of interest are the progress of structural adjustment and farmland use (i.e., prevention of farmland abandonment). As the primary indicator of farmland concentration, I examine the ratio of large farm households managing more than 2 ha[23]. The ratios of the paddy areas rented and of paddy areas accepting various entrusted agricultural work (i.e., all work[24], plowing and puddling, rice planting, and mowing and threshing) capture the extent of farmland rental and outsourcing. Finally, the ratio of area of abandoned farmland measures the level of farmland use.

3.2. Empirical strategy

I adopt a first-difference estimator to estimate the impact of FIPs on structural adjustment. Since the data at hand have only two time points, this is equivalent to a fixed-effect estimator. The

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elderly farmers increased by 59.5% (33.7% in 1990 and 53.8% in 2000; excluding Hokkaido).

[22] As a robustness check, I also apply 50 percentage points as the criterion and obtain similar results.

[23] This is in fact not very large at all, but it is the largest comparable farm size category common to the two censuses.

[24] The difference between rental and the outsourcing of "all farm work" is in whether or not a landowner has outsourced management: if a landowner outsources plot management, then this is considered a rental.

estimated model is

$$\Delta y_i = \alpha + \beta \Delta \%\text{Readjusted}_i + \gamma X_i + \Delta \epsilon_i, \qquad (1)$$

where Δ denotes the difference between 1990 and 2000, y_i is the outcome variable of community i in year t, $\%\text{Readjusted}_{it}$ is the ratio of readjusted farmland, and ϵ_{it} is the error term.

This method utilizes intertemporal variation within each community, so any time-invariant component of omitted variable bias is eliminated. However, in the regressions, I explicitly control for some of the time-invariant community characteristics (X_i) that might affect the *trends* of outcomes: the gradient of paddies, remoteness (i.e., time distance to densely inhibited districts), and zoning (i.e., zoning for city planning area and for agricultural promotion area). Urban areas are designated as city planning areas, and urban planning regulates land use within the area[25]. On the other hand, regions suitable for farming are designated as "agricultural promotion areas." Within an "agricultural promotion area," some zones are further designated as "farmland area," where paddies and upland fields are preserved for agricultural use and conversion to housing or commercial purposes is prohibited. Farmers in the communities under this zoning should be less reluctant to rent out their farmland.

For the second estimation strategy, I use DID estimators, which are often used for policy evaluation. The estimation model is:

$$\Delta y_i = \alpha + \beta D_i + \gamma X_i + \Delta \epsilon_i, \qquad (2)$$

where D_i is the binary treatment dummy. This is simply a replacement of %Readjusted in eq. (1) with a binary variable D_i. The DID estimator compares changes in outcomes between treated and control communities. Comparing the two groups differences out any common trends in the outcomes. Moreover, by differencing the outcomes between the two time points for each community, DID estimators eliminate all the time-invariant variables.

The DID estimators assume that in the absence of treatment, the outcomes of the two groups will follow parallel trends[26]. This is a strong assumption, if the initial characteristics of the two groups are different and if these characteristics are likely to correlate with outcome trends. This is indeed a concern; as I show below, the treated communities tended to have favorable production

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[25] Within a city planning area, there are three zones: an "urbanization-promotion area" promotes urbanization, whereas an "urbanization-control area" prohibits construction and development. There are also "blank areas" that are within the city planning area but not designated as either an "urbanization-promotion area" or an "urbanization-control area."

[26] For a discussion of this issue, see Ravallion (2008) and Chen, Mu, and Ravallion (2009).

conditions. To address this issue, I employ a DID matching strategy as a further robustness check—that is, for each treated community, I match one or several control communities that are alike, based on the covariates or estimated propensity score, and compare the changes in outcomes between the matched communities (Rosenbaum and Rubin 1983; Heckman, Ichimura, and Todd 1997)[27]. Namely, the sample average treatment effect for treated is

$$ATT = \frac{1}{N_1}\sum_{i|D_i=1}\left\{\left(y_{1i,t=1} - y_{1i,t=0}\right) - \sum_{j|D_j=0} w_{ij}\left(y_{0j,t=1} - y_{0j,t=0}\right)\right\}, \qquad (3)$$

where y_{1i} and y_{0j} denote the outcome of treated and control communities, respectively, and $N_1 = \sum_i T_i$, and w_{ij} is the determined weight, depending on the employed matching algorithm. By combining matching with the DID estimator, I can eliminate the time-varying biases based on observables[28].

I apply nearest-neighbor covariate matching and local linear matching as matching algorithms[29]. For the nearest-neighbor covariate matching, I match each treated community with the five or ten control communities that are most alike, based on an inverse variance-weighting matrix (Abadie and Imbens 2002, 2006). I use the bias-correction proposed by Abadie and Imbens (2002), which removes the conditional bias asymptotically. The variance estimator implemented by Abadie and Imbens (2006) is used for estimating the standard errors. For local linear matching, I match the communities based on the propensity scores estimated by probit regression. I use the Epanechnikov distribution as the kernel function and set the bandwidth to 0.1[30]. I obtain standard errors by bootstrapping with 100 repetitions. Samples are restricted to communities that suffice common support, to avoid bad matches[31]. I carry out all the matching with replacement, so that a control community can be matched against different treated communities.

I can make two remarks on issues regarding “treatment” and its effects. First, although I regard FIP implementation to be binary in the DID framework, that implementation could be measured continuously by %Readjusted; it is also possible to add treatment, on top of past projects. For example, a community with a 20% share of readjusted farmland can implement additional projects to increase the share to 60%. This raises the issue of distinguishing the

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[27] See Todd (2008) and Caliendo and Kopeinig (2008) for excellent surveys of program evaluation using matching methods.

[28] Note, however, that time-varying biases caused by unobservable items will remain.

[29] The impact is estimated with Stata 11, using the “nnmatch” (Abadie et al. 2004) and “psmatch2” commands.

[30] I use bandwidths of 0.06, 0.08, 0.1, and 0.2, and the results thereof are quantitatively similar.

[31] In practice, treatment communities whose propensity scores are higher than the maximum or less than the minimum propensity scores of the controls are dropped.

long-term effect of past treatment (20%) from the short-term effect of the additional 40%. In fact, we can expect instantaneous effects as well as long-term effects. As discussed in Section 2, short-term effects can indicate that the project may work as a catalyst to urge retirement among elderly farmers. On the other hand, long-term effects would reflect increased demand or supply, or decreased transaction costs. Since the data at hand have only two time points, separation of these effects is a task left for future research.

Second, the possibility of long-lasting effects raises the issue of defining a comparison group. For example, communities that had not implemented an FIP during our observation period are not suitable for comparison with treated communities that implemented a project during the same period. This is because many of these “untreated” control communities had implemented a project in the past: the mean percentage of readjusted farmland in 1990 among control communities was 76.4%—61.2% points higher than the figure of 15.2% among treated communities ($p < 0.001$). To address these issues, I restrict in the main estimations the samples to communities that never implemented a project before 1990.

4. Results: the impact of FIP on structural adjustment

4.1. First-difference estimates

Table 2, panel A, provides the first-difference estimates. The results reveal that FIPs promote outsourcing. %Readjusted also has a positive association with farmland concentration (i.e., ratio of large farm households) and rental and a negative correlation with farmland abandonment, but the coefficients are not precisely estimated. The coefficients of the time-invariant community characteristics point to how various community conditions correlate with the *trend* of structural adjustment. I find that communities with steeper-gradient paddies tend to have slower structural adjustment trends. The expansion of rental, and therefore farmland concentration, lags behind “flat” communities; outsourcing also lags, but the coefficients are mostly insignificant. Such a tendency is also confirmed for the *level* of outcomes, using simple pooled cross-sectional regressions (not shown). Clearly, structural-adjustment delays in these steeper communities seem to stem from their unfavorable production conditions. Remote communities (measured by time-distance to a densely inhabited district) tend to be left behind in terms of farmland concentration to large farm households and rental expansions. Correlations with outsourcing are complex and the implications thereof are less clear. As expected, rental expansion is larger in communities within the agricultural promotion area, where farmland conversion is prohibited.

Table 2, panel B, addresses the aforementioned possibility of results contamination from the long-lasting effects of past project implementation. The first row reports the estimates of eq. (1), while the second row reports the estimates with pretreatment %Readjusted in 1990, to control for the possible long-lasting effects of past projects. The results in the third row are the estimates using a restricted sample of communities that were never treated prior to 1990 (i.e., %Readjusted in 1990 is 0). In addition to eliminating the long-lasting effects of past projects, the sample restriction has the benefit of increasing the precision of estimates, because it excludes many communities in which the dependent variable did not change over time[32]. The results reveal that the absolute values of the coefficients tend to become larger from the first row to the third row, suggesting that the project impact is underestimated due to the long-lasting effects. Thus, it is crucial to account for this bias.

The coefficients in the third row indicate that if all the paddies in a never-treated community were readjusted (i.e., %Readjusted increases by 100%), the ratios of area accepting plowing and puddling, rice planting, and mowing and threshing would increase by 2.7, 1.3, and 2.3 percentage points, respectively. These are quite sizable increases, given that the initial levels of those ratios in 1990 for never-treated communities were fairly low: 2.0%, 1.4%, and 2.7%, respectively. Thus, full readjustment is associated with the effect that roughly doubles the initial ratio of areas that outsource this work.

4.2. Difference-in-differences and matching estimates

In the analysis below, I use the binary treatment indicator and examine the impact within the DID framework of FIPs. I also restrict the sample to the 1,094 communities for which %Readjusted was 0 in 1990, to cope with underestimation due to long-lasting effects. Even so, I still keep 61.1% (i.e., 496 of 812) of the communities that implemented FIPs during the observation period. Of the 1,094 never-treated communities, 496 had been treated by 2000; the remaining 598 communities form the control group. Since these communities had not implemented FIPs before 1990, the estimates are likely to be at the upper limit; however, the restricted sample tends to exhibit fewer favorable production conditions than those that had some farmland readjustment before 1990[33]. Thus, the estimates should be lower than the actual impact of the project for communities with average conditions.

Before addressing the DID estimates, I first check the determinants of project implementation. **Table 3** reports the probit estimates of the determinants of FIP implementation. The results imply that the communities with relatively favorable conditions tended to implement FIPs: treated communities were likely to have flatter gradients and be relatively close to urban areas. Zoning also seems to matter: treated communities were either likely to be within an urbanization promotion area or within an agricultural promotion area. These findings imply that

[32] In our case, %Readjusted did not change from 1990 to 2000 in 1,694 of the 4,780 communities, because all of their farmland had already been fully readjusted by 1990. Inclusion of these communities in the estimation would have increased standard errors.

[33] The percentage of communities with a steep gradient was 41.4% among communities with no farmland readjustment prior to 1990 and 11.0% among communities that had at least some farmland readjustment before 1990 ($p < 0.001$ for all comparisons).

outcome *trends* between treated and control communities might derive from differences in initial community conditions, which could lead to the overestimation of the impact of FIPs.

I employ a matching strategy to eliminate the potential time-variant bias caused by differences in initial community conditions. The propensity scores used for local linear matching are obtained from the probit regression (**table 3**). After matching, the treated and control groups should be similar in terms of their distributions of community characteristics. I check balancing by the mean absolute standardized bias proposed by Rosenbaum and Rubin (1985) and the test proposed by Sianesi (2004). **Table A1** in the Appendix reports the results of the balancing test for local linear matching. The mean absolute standardized biases are sufficiently below the critical level of 20% suggested by Rosenbaum and Rubin (1985). The pseudo R^2 obtained from probit regression after matching is close to 0, and the likelihood ratio test of joint significance of the regressors implies that there is no systematic difference between the treated and control groups.

Table 4 provides DID estimates. Panels A and B report simple unmatched-DID estimates, and panel C reports matched-DID estimates. The estimates in panel A are derived from regressions, with the readjustment indicator as the only explanatory variable. The coefficient of the readjustment dummy measures the difference in the changes of unconditional means of outcomes between treated and control communities; the constant measures changes among control communities. The estimates in panel B control for time-invariant community characteristics.

The results are mostly qualitatively similar and consistent, except for the sign of the ratio of large farm households, which turns negative after matching. The magnitude of the coefficients are slightly smaller than the first-difference estimates (third row of table 2, panel B), since the mean coverage of readjustment for treated communities is 87.2% (compared to 100% for the reading of the results in table 2). The magnitude and statistical significance of the coefficients do vary to some extent, depending on whether the samples are matched and on the algorithm used for matching[34]. The results show that in most cases, the impact on the outsourcing of each of plowing and puddling, rice planting, and mowing and threshing is significantly positive. A simple

[34] For example, the percentage of the area of paddies in which plowing and puddling for the treated communities in 1990 had been outsourced was 2.51%. Panel A indicates that the trend from 1990 to 2000 increased this ratio by 0.28 percentage points (i.e., a change in control communities or in the magnitude of the constant). In addition, the FIP added another 2.32 percentage points for treatment communities, thus roughly doubling the ratio ((0.0251 + 0.0028 + 0.0232)/0.025 = 2.04). Since the mean area of paddies for the treated communities in 1990 was 28.2 ha, these communities increased the outsourced area from 0.71 ha (=28.2 ha × 0.0251) to 1.43 ha (=0.71 ha × 2.04). Similarly, the effects on planting, and mowing and threshing are 0.58 ha to 1.24 ha (215%) and 0.98 ha to 1.56 ha (159%), respectively.

calculation indicates that the treated communities roughly doubled their outsourced areas[35]. The negative estimates on the ratio of abandoned farmland imply that the FIPs slowed down farmland abandonment, but the coefficients are no longer significant after matching.

In summary, the results suggest that FIPs contributed to expansions in outsourcing. The impact of FIPs on farmland concentration in terms of the appearance of a greater number of large farm households, more rentals, and the prevention of farmland abandonment is in the expected direction, but it is not statistically significant. The finding that structural adjustment proceeded in outsourcing rather than in purchase or rental is consistent with the argument that improvements in farming conditions, as brought about by FIPs, make it possible for even small-scale and elderly farmers to continue farming, thereby reducing farmland supplies (Kondo 1998; Kunimitsu 2008). In fact, many elderly farmers do prefer to manage their farmland on their own, for as long as they are capable. As farmers age, they start to outsource work that requires strength or is considered dangerous. Even so, it is not unusual for elderly farmers to hold ownership while outsourcing most of the core operations[36]. In this context, it may not be necessary for farmland concentration to proceed in the forms of purchase or rental. Outsourcing can serve as a solution, as long as it helps reduce production costs and prevent farmland from being abandoned.

5. Farmland improvement projects and deterioration of agricultural labor

Thus far, the evidence suggests that in Japan, FIPs fostered structural adjustments in the form of outsourcing, without pushing farmers to exit the agricultural sector. In this section, I specifically examine the effect of FIPs on labor deterioration. For this purpose, I conduct an exploratory regression on the covariates of farmers' exit, aging, and part-time farming.

Table 5 reports the DID estimates while using the restricted sample. The coefficients of the constants confirm the general trend of the decline in the number of farm households and the rise in the proportion of elderly farmers. Such tendencies are more prominent in communities with a steeper gradient. Again, such unfavorable production conditions seem to accelerate deterioration. On the other hand, communities within agricultural promotion areas experienced slower trends in farmers' exit and aging. The coefficients of the readjustment dummy and its interactions with gradient dummies help one examine the effect of FIPs on labor deterioration. Columns (2) and (3) indicate that FIPs slow down farmers' exit; this effect, however, is weaker (though not statistically significantly so) in steeper communities. On the other hand, FIPs slow down the trend

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[35] Note that the ratio of abandoned farmland is actually *increasing*, even in treated communities; FIPs are only slowing it down. The magnitude of the constant in the DID estimate is positive and greater than the absolute value of the coefficient of the readjustment dummy.

[36] Most often, even after outsourcing most of the heavy machinery work, elderly farmers tend to continue daily water control—an activity that requires experience but not strength and is critical to the quality of produce (i.e., rice).

of farmer aging in steeper communities, compared to “flat” communities.

These results seem to imply that improvements in production conditions due to FIPs enable farmers to continue farming in “flat” communities, but that they encourage farmers’ exit in steeper communities by promoting elderly farmer retirement. This should influence the mode of structural adjustment. In “flat” communities, structural adjustment would occur through rental and outsourcing, since farmers stay and continue to farm; in steeper communities, on the other hand, structural adjustment is more likely to proceed through the reallocation of farmland, because farmers exit. **Table 6** supports this hypothesis: it reports the unmatched-DID estimates of the readjustment dummy and its interactions with gradient dummies on structural adjustment, and the results show a clear pattern that the impact of FIPs on rental and outsourcing is stronger for “flat” communities than for steeper communities. On the other hand, structural adjustment in steeper communities tends to proceed through the concentration of farmland toward large farm households.

6. Concluding remarks

In the agricultural sector of an industrialized economy, structural adjustment and farmland concentration are the bases for improving productivity, by harnessing economies of scale. In this study, I focused on farmland fragmentation, a physical barrier that could potentially hamper structural adjustment in many developing and developed countries around the world. I investigated the impact of Farmland Improvement Projects (FIPs) in Japan, by which small plots of land are merged and enlarged, often consolidating parcels among farmers. FIPs are expected to improve productivity and facilitate farmland transactions through stimulated supply and demand and lower transaction costs, and prevent farmland abandonment.

The results reveal that FIPs facilitated the outsourcing of agricultural work—which is a form of farmland-use concentration—at the operational level, to core farmers. The correlation with the extent of rentals and the prevention of farmland abandonment was positive but not precisely estimated. I also found that FIPs have some effect in helping farmers remain in the agricultural sector. Thus, FIPs seem to have promoted structural adjustment in the form of outsourcing, without reducing the number of farmers, rather than facilitating farmland concentration through purchase or rental.

Of exit and farmland concentration (purchase and rental) and continuation and outsourcing, which mode of structural adjustment is most desirable? The primary intention of structural adjustment is to improve efficiency, so the question is which mode of structural adjustment best reduces production costs? While a detailed study is required to answer this question, the answer could potentially depend on the extent of farmland fragmentation. If a core farmer cannot expand his farm size (through purchase or rental) without exacerbating fragmentation, then the concentration of farmland could be costly, because it would increase recurrent travelling costs (Kawasaki 2010). Such costs could be reduced via outsourcing, because each farm household undertakes its own, separate daily management for its own plots. Another viewpoint considers the ability to prevent farmland abandonment: the results of examinations of outsourcing imply that small-scale or elderly farmers are still taking some part in farming. This sustains their engagement in farming and contributes to the collective management of common pool resources—such as irrigation, drainage, and farm road infrastructure—that are important factors in preventing farmland abandonment. Thus, the modes of structural adjustment may have different implications with regard to reducing production costs and preventing farmland abandonment; the optimal choice of mode seems to be context-dependent. More study is needed to assess the desirability of various structural-adjustment modes.

The case study of Japan suggests that projects similar to FIPs may help other countries alleviate farmland fragmentation and facilitate the concentration of farmland among efficient and motivated farmers. However, such projects tend to be quite expensive. A rigorous cost–benefit analysis should be conducted prior to any project implementation. The results of heterogeneous effects may suggest the selective use of resources in areas that have less favorable conditions. Finally, it should be noted that since FIPs facilitate land concentration, care might be needed to avoid possibly adverse effects on small farmers and agricultural laborers.

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Table 1. Summary statistics of variables

Variable	Definition	1990 Mean	1990 S.D.	2000 Mean	2000 S.D.	% change
Labor						
Number of farm households	Total number of farm households	23.7	18.9	18.9	15.7	-0.203
Number of farmers	Population engaged in farming	33.2	29.3	28.8	26.0	-0.133
Number of large farm households		3.2	4.9	2.6	4.0	-0.181
Number of elderly famers	Population engaged in farming above 65 years old	11.7	10.4	16.1	13.9	0.375
Number of part-time farm households		22.0	17.8	17.0	14.5	-0.226
Ratio of large farm households		0.211	0.244	0.242	0.259	0.145
Ratio of elderly farmers	Denominator = total population engaged in farming	0.364	0.165	0.577	0.178	0.584
Ratio of part-time farm households	Denominator = total number of farm households	0.922	0.114	0.891	0.140	-0.033
Land (units in 1a=0.01ha)						
Area of paddy, managed	(owned)-(rent-out)-(abandoned)+(rent-in)	2974.3	3009.2	2726.9	2932.1	-0.083
Area of paddy, rent-in		362.2	481.0	557.8	750.2	0.540
Area of paddy, rent-out		97.4	199.1	90.5	172.4	-0.070
Area of paddy, owned		2709.4	2749.3	2259.6	2421.7	-0.166
Area of paddy under outsourcing…	Area of paddy accepting various agricultural works					
All services		35.2	167.1	42.0	387.4	0.192
Plowing and puddling		99.3	296.1	119.9	537.3	0.207
Rice planting		97.0	282.1	135.7	422.6	0.398
Mowing and threshing		151.9	362.8	192.2	539.6	0.265
Area of farmland, owned	farmland = paddy+upland+orchard	3043.9	3027.0	2519.6	2664.5	-0.172
Area of farmland, abandoned	farmland = paddy+upland+orchard	83.3	175.8	91.8	147.1	0.102
Area of paddy, abandoned		N.A.	N.A.	56.1	97.9	
Area of farmland*	Area-based, farmland = paddy+upland+orchard	N.A.	N.A.	3527.4	3654.4	
Area of paddy*	Area-based	3264.3	3320.3	3067.3	3304.3	-0.060
Area of paddy, readjusted*	Area-based	2477.4	3299.5	2688.3	3351.0	0.085
Ratio of area of paddy, readjusted*	Area-based	0.654	0.423	0.766	0.368	0.172
Treatment indicator						
Ratio of readjusted paddy	Denominator=Area of paddy; area-based	0.654	0.423	0.766	0.368	
Readjustment dummy	Dummy, 1 if (i) the area of readjusted paddy increased between 1990 and 2000, and (ii) the ratio of readjusted paddy increased more than 25 % points; area based			0.171		
Outcomes						
Ratio of area rented-in	Denominator = Area of paddy, managed	0.117	0.104	0.187	0.143	0.595
Ratio of area accepting…	Denominator = Area of paddy, managed					
All services	Denominator = Area of paddy, managed	0.012	0.066	0.014	0.116	0.140
Plowing and puddling	Denominator = Area of paddy, managed	0.036	0.099	0.043	0.147	0.213
Rice planting	Denominator = Area of paddy, managed	0.031	0.086	0.045	0.124	0.433
Mowing and threshing	Denominator = Area of paddy, managed	0.049	0.110	0.064	0.168	0.299
Ratio of abandoned farmland	Denominator = (Area of owned farmland+area of abandoned farmland)	0.044	0.082	0.056	0.085	0.279
Community characteristics						
Gradient (paddies)						
Flat (reference category)	Gradient of paddies <1/100			0.529		
Gentle	Gradient of paddies 1/100 to 1/20			0.287		
Steep	Gradient of paddies 1/20			0.184		
Distance to DID (densely inhibited district)						
<0.5 hour (reference category)				0.772		
0.5-1.0 hour				0.178		
1.0-1.5 hour				0.047		
>1.5 hour				0.003		
Zoning for city planning area						
Not in city planning area (reference category)				0.412		
Urbanization promotion area				0.021		
Urbanization control area				0.231		
Blank area	Within city planning area but not designated for urbanaization promotion are ore urbanization control area			0.336		
Zoning for agricultural promotion area						
Not in agricultural promotion area (reference category)				0.034		
Blank area	Within agricultural promotion area but not designated as farmland			0.075		
Farmland area	Designated as farmland			0.891		

Note: Figures are aggregate of management-level data in each community (farmer basis), except for variables denoted with an asterisk, which are on an area basis. The area of paddy rent-out is smaller than the area of paddy rent-in, primarily because non-farmer landowners rent-out their farmland but were not covered in the Census, as they are not farmers.

Table 2. First-difference estimates

Dependent variable: Change in ratio of…	Large farmers	Area rent-in	Area under outsourcing: All work	Plowing and puddling	Rice planting	Mowing and threshing	Abandoned farmland
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A.							
Change in ratio of readjusted paddies	-0.00280	-0.00379	0.0104	0.0166**	0.00853*	0.00199	-0.0134
	(0.00472)	(0.00506)	(0.0102)	(0.00681)	(0.00504)	(0.00616)	(0.0144)
Gradient (gentle)	-0.00987***	-0.00608	-0.00282	-0.00536	0.00382	-0.00675	0.0194
	(0.00338)	(0.00385)	(0.00536)	(0.00601)	(0.00491)	(0.00627)	(0.0203)
Gradient (steep)	-0.0151***	-0.0138***	-0.00527	-0.00753	-0.00902*	-0.000999	-0.0196
	(0.00371)	(0.00502)	(0.00424)	(0.00719)	(0.00547)	(0.0107)	(0.0149)
Distance to DID (0.5 to 1 hr)	-0.00706*	-0.00602	0.00175	-0.00914*	-0.00103	-0.00368	-0.0145
	(0.00376)	(0.00483)	(0.00395)	(0.00501)	(0.00438)	(0.00610)	(0.0158)
Distance to DID (1 to 1.5 hr)	-0.0116**	-0.00566	0.000966	0.0216	0.0132*	0.0320***	0.00235
	(0.00496)	(0.00911)	(0.00729)	(0.0146)	(0.00796)	(0.0123)	(0.0141)
Distance to DID (more than 1.5 hr)	0.0118	0.00215	-0.0629**	0.0430	0.0378	0.0354	-0.0319
	(0.0222)	(0.0469)	(0.0317)	(0.0590)	(0.0438)	(0.0509)	(0.0476)
City planning area	-0.000385	0.0303	0.0207**	-0.0548	0.00242	-0.0682	-0.0168
(Urbanization promotion area)	(0.0166)	(0.0189)	(0.00896)	(0.0545)	(0.0103)	(0.0570)	(0.0234)
City planning area	-0.00918**	-0.000570	0.00691	-0.0141**	-0.00317	-0.00620	-0.0144
(Urbanization control area)	(0.00452)	(0.00449)	(0.00580)	(0.00617)	(0.00527)	(0.00649)	(0.0166)
City planning area	-0.00579*	-0.00652*	0.00206	-0.0153***	-0.00861*	-0.00767	-0.0272
(Blank area)	(0.00342)	(0.00391)	(0.00457)	(0.00533)	(0.00485)	(0.00691)	(0.0240)
Agricultural promotion area	-0.0109	0.0294*	0.0103	-0.00468	0.0577***	-0.0190	0.0836
(Blank area)	(0.0106)	(0.0168)	(0.00757)	(0.0627)	(0.0147)	(0.0649)	(0.0919)
Agricultural promotion area	0.00101	0.0367**	0.00984	-0.0541	0.0117	-0.0673	-0.0151
(Farmland area)	(0.00968)	(0.0155)	(0.00723)	(0.0615)	(0.00822)	(0.0642)	(0.0129)
Constant	0.0400***	0.0436***	-0.0103	0.0681	0.00236	0.0832	0.0355
	(0.0102)	(0.0157)	(0.00842)	(0.0635)	(0.00970)	(0.0662)	(0.0216)
Observations	4,648	4,647	4,647	4,647	4,647	4,647	4,679
Adjusted R^2	0.007	0.007	0.002	0.016	0.014	0.011	0.004
Panel B. (coefficients of the ratio of readjusted paddies)							
Full sample, without %Readjusted in 1990	-0.00280	-0.00379	0.0104	0.0166**	0.00853*	0.00199	-0.0134
	(0.00472)	(0.00506)	(0.0102)	(0.00681)	(0.00504)	(0.00616)	(0.0144)
Full sample, with %Readjusted in 1990	0.00536	0.00626	0.00557	0.0188**	0.0105*	0.0126	0.0186
	(0.00545)	(0.00680)	(0.00802)	(0.00744)	(0.00552)	(0.00796)	(0.0152)
Restricted sample, without %Readjusted in 1990	0.00819	0.0127	0.0142	0.0271***	0.0127**	0.0229**	-0.00739
	(0.00794)	(0.00982)	(0.00961)	(0.00999)	(0.00629)	(0.00992)	(0.0165)

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively. Robust standard error reported in parenthesis. Omitted categories of the dummy variables are: "flat" for "agricultural area," "less than 30 minutes" for "distance to DID," "not in city planning area" for "city planning area," and "not in agricultural promotion area" for "agricultural promotion area." Results in panel B control for change in time-variant community characteristics (e.g., ratio of part-time farmers, ratio of elderly farmers, and number of farm households). "With initial value" indicates that the 1990 value of ratio of readjusted farmland is included as an independent variable. "Restricted samples" refer to communities with a zero ratio of readjusted farmland in 1990.

Table 3. Probit estimates of project placement (marginal effects)

	(1)
Gradient (gentle)	-0.250***
	(0.0402)
Gradient (steep)	-0.453***
	(0.0372)
Distance to DID (0.5 to 1 hr)	-0.121***
	(0.0393)
Distance to DID (1 to 1.5 hr)	-0.196***
	(0.0573)
Distance to DID (more than 1.5 hr)	-0.101
	(0.274)
City planning area	0.454***
(Urbanization promotion area)	(0.101)
City planning area	-0.0103
(Urbanization control area)	(0.0573)
City planning area	-0.0394
(not designated)	(0.0422)
Agricultural promotion area	0.330***
	(0.0925)
Agricultural promotion area	0.336***
(farmland)	(0.0777)
Ratio of part-time farmers	0.188
	(0.140)
Ratio of elderly farmers	-0.143
	(0.0991)
Number of farm households	0.00305***
	(0.00107)
Observations	1077
LR Chi^2 (13)	246.7
Pseudo R^2	0.166
Log likelihood	-619.8

Note: *, **, and *** indicate statistical significance at the 10%; 5%; and 1% levels respectively. Robust standard error reported in parentheses. The dependent variable is the treatment dummy. The coefficients are marginal effects evaluated at the mean.

Table 4. Difference-in-differences and matching estimates

Dependent variable: Change in ratio of…	Large farmers	Area rent-in	Area under outsourcing: All work	Area under outsourcing: Plowing and puddling	Area under outsourcing: Rice planting	Area under outsourcing: Mowing and threshing	Abandoned farmland
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. DID Estimates (OLS, raw difference)							
Readjustment dummy	0.00725	0.00686	0.0143	0.0242***	0.0112*	0.00842	-0.0117*
	(0.00580)	(0.00747)	(0.0118)	(0.00879)	(0.00665)	(0.00833)	(0.00653)
Constant	0.0173***	0.0566***	-0.000375	0.00283	0.0123***	0.0121**	0.0249***
	(0.00340)	(0.00549)	(0.00166)	(0.00295)	(0.00334)	(0.00470)	(0.00537)
Observations	1,073	1,072	1,072	1,072	1,072	1,072	1,073
Adjusted R^2	0.002	0.001	0.002	0.008	0.003	0.001	0.003
Panel B. DID Estimates（OLS, with time-invariant community characteristics)							
Readjusted dummy	0.00706	0.00683	0.00928	0.0238***	0.00929*	0.0185**	-0.00965
	(0.00654)	(0.00842)	(0.00640)	(0.00844)	(0.00554)	(0.00834)	(0.00750)
Constant	0.00704	0.0208	-0.00103	0.0422**	0.0355**	0.0409	0.00601
	(0.0156)	(0.0277)	(0.00626)	(0.0211)	(0.0162)	(0.0253)	(0.0191)
Observations	1,065	1,064	1,064	1,064	1,064	1,064	1,065
Adjusted R^2	0.006	0.009	0.007	0.067	0.060	0.044	0.020
Panel C. DID-matching estimates (ATT of farmland readjustment)							
Covariate matching (n = 5)	-0.00349	0.0125	0.0143	0.0284***	0.0205***	0.0185**	-0.0133
	(0.00936)	(0.00924)	(0.0111)	(0.00799)	(0.00617)	(0.00779)	(0.00928)
Covariate matching (n = 10)	-0.00275	0.0106	0.0146	0.0254***	0.0200***	0.0168*	-0.0124
	(0.00787)	(0.00840)	(0.00909)	(0.00886)	(0.00678)	(0.00872)	(0.00815)
PSM: local linear (bw = 0.06)	-0.000846	0.00714	0.0149	0.0269***	0.0178***	0.0151	-0.00626
	(0.00878)	(0.00901)	(0.0128)	(0.00977)	(0.00646)	(0.00982)	(0.00754)
PSM: local linear (bw = 0.1)	-0.00246	0.00562	0.0150	0.0271***	0.0179***	0.0155*	-0.00633
	(0.00719)	(0.00807)	(0.0118)	(0.00869)	(0.00616)	(0.00877)	(0.00681)

Note: *, **, and *** indicate statistical significance at the 10%; 5%; and 1% levels respectively. Robust standard error reported in parentheses. Time-invariant community characteristics controlled in Panel B are dummies of gradient, distance to densely inhabited district, city planning zone, and agricultural promotion area. For covariate matching in panel C, the standard errors are estimated by the variance estimator suggested by Abadie and Imbens (2006). Propensity score matching in panel C was performed based on local linear matching with replacement using an Epanechnikov kernel. The standard errors were obtained from bootstrapping with 100 repetitions. A common support was imposed.

Table 5. Difference-in-differences estimates on agricultural labor

	% change in number of farm households (1)	% change in number of farm households (2)	% change in number of farm households (3)	Change in ratio of elderly farmers (4)	Change in ratio of elderly farmers (5)	Change in ratio of elderly farmers (6)	Change in ratio of part-time farm households (7)	Change in ratio of part-time farm households (8)	Change in ratio of part-time farm households (9)
Panel A. DID estimates									
Readjusted dummy		0.0751***	0.0966***		0.00127	0.0395		0.00230	0.0125
		(0.0145)	(0.0265)		(0.0153)	(0.0303)		(0.0121)	(0.0241)
Readjusted dummy*			-0.0110			-0.0817**			0.00136
gradient (gentle)			(0.0378)			(0.0407)			(0.0296)
Readjusted dummy*			-0.0461			-0.0299			-0.0274
gradient (steep)			(0.0343)			(0.0378)			(0.0320)
Gradient (gentle)	-0.0431**	-0.0243	-0.0141	0.0126	0.0129	0.0599*	-0.0172	-0.0167	-0.0149
	(0.0184)	(0.0185)	(0.0306)	(0.0205)	(0.0209)	(0.0346)	(0.0121)	(0.0130)	(0.0268)
Gradient (steep)	-0.117***	-0.0826***	-0.0617**	0.0440**	0.0445**	0.0695**	-0.0389***	-0.0379**	-0.0266
	(0.0195)	(0.0199)	(0.0292)	(0.0208)	(0.0220)	(0.0325)	(0.0126)	(0.0151)	(0.0248)
Distance to DID (0.5 to 1 hr)	-0.0241	-0.0149	-0.0135	0.00412	0.00427	0.00357	-0.00549	-0.00523	-0.00416
	(0.0179)	(0.0177)	(0.0177)	(0.0188)	(0.0189)	(0.0190)	(0.0120)	(0.0120)	(0.0122)
Distance to DID (1 to 1.5 hr)	0.0169	0.0316	0.0324	-0.0203	-0.0201	-0.0207	0.0372*	0.0376**	0.0383**
	(0.0322)	(0.0320)	(0.0319)	(0.0308)	(0.0306)	(0.0304)	(0.0192)	(0.0192)	(0.0191)
Distance to DID (more than 1.5 hr)	-0.0888	-0.0790*	-0.0687	0.0294	0.0296	0.0131	0.00129	0.00154	0.00998
	(0.0692)	(0.0457)	(0.0503)	(0.0459)	(0.0457)	(0.0504)	(0.103)	(0.103)	(0.104)
City planning area	0.0847	0.0558	0.0492	-0.122**	-0.123**	-0.128**	0.0210	0.0202	0.0164
(Urbanization promotion area)	(0.0677)	(0.0678)	(0.0680)	(0.0488)	(0.0490)	(0.0501)	(0.0456)	(0.0454)	(0.0445)
City planning area	-0.00238	-0.00218	-0.00425	-0.0131	-0.0131	-0.0178	0.0193	0.0193	0.0186
(Urbanization control area)	(0.0239)	(0.0234)	(0.0236)	(0.0231)	(0.0231)	(0.0233)	(0.0138)	(0.0138)	(0.0135)
City planning area	0.0332*	0.0364**	0.0368**	-0.0237	-0.0237	-0.0232	0.00935	0.00947	0.00974
(Blank area)	(0.0177)	(0.0175)	(0.0175)	(0.0197)	(0.0197)	(0.0197)	(0.0117)	(0.0117)	(0.0116)
Agricultural promotion area	0.0571	0.0373	0.0332	-0.0893*	-0.0896*	-0.0833*	0.0187	0.0182	0.0149
(Blank area)	(0.0432)	(0.0431)	(0.0432)	(0.0474)	(0.0476)	(0.0474)	(0.0353)	(0.0352)	(0.0353)
Agricultural promotion area	0.142***	0.120***	0.117***	-0.0573	-0.0576	-0.0540	-0.00316	-0.00375	-0.00583
(Farmland)	(0.0388)	(0.0387)	(0.0388)	(0.0420)	(0.0423)	(0.0425)	(0.0339)	(0.0338)	(0.0339)
% change in number of farmers				0.0840***	0.0840***	0.0853***			
				(0.0228)	(0.0228)	(0.0231)			
% change in number of farm households							-0.0649**	-0.0655**	-0.0667**
							(0.0275)	(0.0281)	(0.0279)
Constant	-0.350***	-0.388***	-0.400***	0.290***	0.289***	0.259***	-0.0422	-0.0436	-0.0492
	(0.0429)	(0.0434)	(0.0468)	(0.0451)	(0.0460)	(0.0483)	(0.0369)	(0.0387)	(0.0458)
Observations	1,081	1,081	1,081	1,056	1,056	1,056	1,065	1,065	1,065
Adjusted R^2	0.083	0.103	0.104	0.041	0.041	0.045	0.029	0.029	0.031

Note: *, **, and *** indicate statistical significance at the 10%; 5%; and 1% levels respectively. Robust standard error reported in parentheses.

Table 6. Heterogeneous effects by gradient of paddies

Dependent variable: Change in ratio of...	Large farmers	Area rent-in	Area under outsourcing: All work	Plowing and puddling	Rice planting	Mowing and threshing	Abandoned farmland
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Readjustment dummy	-0.0138	0.0184	0.0203	0.0451***	0.0385***	0.0536**	-0.00732
	(0.0126)	(0.0125)	(0.0181)	(0.0156)	(0.0111)	(0.0228)	(0.0106)
Readjustment dummy *	0.0383**	-0.00193	-0.00650	-0.0475**	-0.0390**	-0.0561**	0.00800
gradient (gentle)	(0.0184)	(0.0209)	(0.0188)	(0.0215)	(0.0174)	(0.0266)	(0.0158)
Readjustment dummy *	0.0214	-0.0283	-0.0229	-0.0144	-0.0424***	-0.0428*	-0.0128
gradient (steep)	(0.0147)	(0.0187)	(0.0179)	(0.0229)	(0.0134)	(0.0246)	(0.0183)
Observations	1,065	1,064	1,064	1,064	1,064	1,064	1,065
Adjusted R^2	0.011	0.011	0.007	0.071	0.066	0.050	0.021

Note: *, **, and *** indicate statistical significance at the 10%; 5%; and 1% levels respectively. Robust standard error reported in parentheses. Other controls are dummies of gradient, distance to densely inhabited district, city planning zone, and agricultural promotion area.

Table A1. Balancing test

	Unmatched				Matched			
	Mean			t-test	Mean			t-test
Variable	Treated	Control	%bias	p-value	Treated	Control	%bias	p-value
Panel A. Bandwidth=0.06								
Ratio of part-time farm households	0.924	0.898	22.2	0.000 ***	0.924	0.911	10.9	0.066 *
Ratio of elderly farmers	0.371	0.392	-12.9	0.038 **	0.372	0.370	1.2	0.845
Number of farm households	22.5	18.0	28.1	0.000 ***	22.0	23.1	-7.1	0.322
Gradient (paddies)								
Gentle	0.271	0.283	-2.7	0.664	0.275	0.250	5.5	0.381
Steep	0.222	0.567	-75.3	0.000 ***	0.225	0.243	-3.9	0.513
Distance to DID (densely inhibited district)								
0.5-1.0 hour	0.202	0.382	-40.3	0.000 ***	0.205	0.202	0.7	0.898
1.0-1.5 hour	0.046	0.108	-23.1	0.000 ***	0.047	0.049	-0.9	0.866
>1.5 hour	0.002	0.004	-2.9	0.644	0.002	0.003	-1.2	0.838
Zoning for city planning area								
Urbanization promotion area	0.020	0.002	17.7	0.003 ***	0.012	0.019	-6.4	0.400
Urbanization control area	0.228	0.083	40.9	0.000 ***	0.230	0.229	0.2	0.984
Blank area	0.287	0.265	4.9	0.427	0.289	0.286	0.6	0.921
Zoning for agricultural promotion area								
Blank area	0.145	0.143	0.7	0.914	0.145	0.151	-1.5	0.813
Farmland area	0.818	0.811	1.9	0.763	0.824	0.811	3.2	0.619
Pseudo R^2				0.164				0.005
LR Chi^2				240.1				6.84
p > chi^2				0.000 ***				0.910
Observations off-support				0				7
Observations on-support				566				488
Panel B. Bandwidth = 0.1								
Ratio of part-time farm households	0.924	0.898	22.2	0.000 ***	0.924	0.910	11.5	0.054 *
Ratio of elderly farmers	0.371	0.392	-12.9	0.038 **	0.372	0.371	0.5	0.935
Number of farm households	22.5	18.0	28.1	0.000 ***	22.0	23.3	-8.2	0.257
Gradient (paddies)								
Gentle	0.271	0.283	-2.7	0.664	0.275	0.248	5.9	0.344
Steep	0.222	0.567	-75.3	0.000 ***	0.225	0.243	-3.9	0.512
Distance to DID (densely inhibited district)								
0.5-1.0 hour	0.202	0.382	-40.3	0.000 ***	0.205	0.206	-0.3	0.952
1.0-1.5 hour	0.046	0.108	-23.1	0.000 ***	0.047	0.053	-2.2	0.681
>1.5 hour	0.002	0.004	-2.9	0.644	0.002	0.003	-1.2	0.838
Zoning for city planning area								
Urbanization promotion area	0.020	0.002	17.7	0.003 ***	0.012	0.024	-11.7	0.159
Urbanization control area	0.228	0.083	40.9	0.000 ***	0.230	0.228	0.5	0.948
Blank area	0.287	0.265	4.9	0.427	0.289	0.284	1.2	0.856
Zoning for agricultural promotion area								
Blank area	0.145	0.143	0.7	0.914	0.145	0.144	0.5	0.944
Farmland area	0.818	0.811	1.9	0.763	0.824	0.812	3.1	0.624
Pseudo R^2				0.164				0.007
LR Chi^2				240.1				9.38
p > chi^2				0.000 ***				0.744
Observations off-support				0				7
Observations on-support				566				488

Note: *, **, and *** indicate statistical significance at the 10%; 5%; and 1% levels respectively.

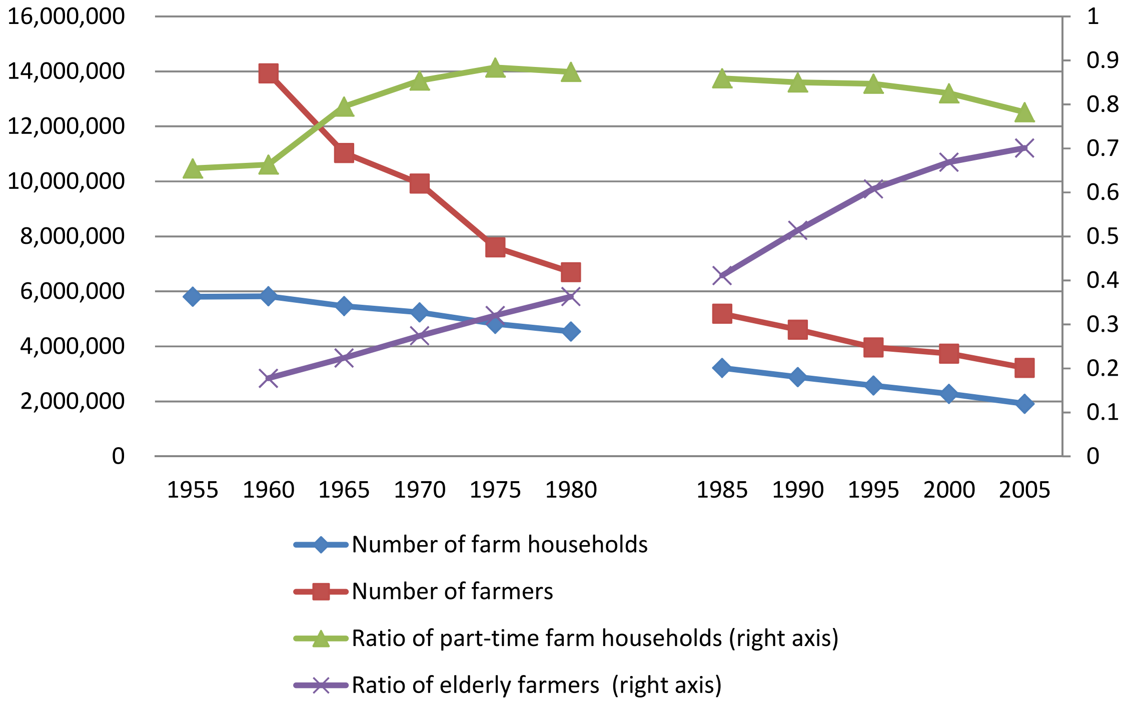

Figure 1. Trends in agricultural labor

Source: MAFF (2007).

Note: Figures are aggregate of all Japanese farm households, excluding those in Hokkaido. Due to changes in definitions, there is no continuity in the figures between 1980 and 1985. Figures after 1985 pertain to commercial farm households.

a) Before. Plots had irregular shapes, and their sizes averaged 0.05–0.07 ha each.

b) After. Plots were reshaped and enlarged to a mean plot size of 0.5 ha each.

Figure 2. An example of a farmland consolidation project in Niigata, Japan
Source: Niigata Prefecture Website: http://www.pref.niigata.lg.jp/HTML_Article/003kajikawaugann.pdf