Impact of land readjustment project on farmland use and structural adjustment: The case of Niigata, Japan*

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1. Introduction

Farmland fragmentation is a commonly observed phenomenon in many countries in Asia (e.g., China, Japan, India, Taiwan, and Vietnam) as well as in Central and East Europe (Heston and Kumar, 1983; Niroula and Thapa, 2005; Ram, Tsunekawa, Sahad and Miyazaki, 1999; Sikor, Muller and Stahl, 2009; Tan, Heernik, and Qu, 2006). Small and fragmented farmland tends to lower productivity by inhibiting the use of large agricultural machines and by increasing transportation costs and work hours. As a result, farmland fragmentation sometimes ends up in abandonment of farmland (Sikor, Muller and Stahl, 2009). The inefficiency caused by farmland fragmentation is 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, 2009). It is now widely acknowledged that the dissolution of farmland fragmentation is one of the key challenges in promoting growth of agricultural sector in these countries.

Japan is one country that suffers from serious farmland fragmentation. It is reported that even *core farmers*[1] face the issue; a survey conducted by Ministry of Agriculture, Forestry and Fisheries (MAFF) indicates that plots of the studied farmers whose average operation size is 14.8 ha, are dispersed over, in average, 28.5 separate blocks (MAFF, 2008). At the same time, smallness of operation size[2] has been considered as the major cause of low productivity in Japanese agriculture due to lack of economies of scale. Efforts of structural adjustment to concentrate farmland to large and efficient core farmers through purchase, rental, or outsourcing of agricultural work has been unsuccessful, partly due to small and fragmented plots. Unprofitability of agriculture and aging of farmers is causing farmland abandonment which reached 386,000 ha in 2005[3].

A potential physical solution to resolve farmland fragmentation is farm consolidation or farmland readjustment (Pasakarnis and Maliene, 2010; Thomas 2006; Vitikainen, 2004). Farmland consolidation is a public project that consists of farmland readjustment that reshapes and enlarges small dispersed plots into large plots, and development of infrastructure such as irrigation, drainage,

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

[2] The national average operation size is 1.91 ha per farmer in 2009. The average operation size for *business farm household* whose farm income is more than half of total household income and which has at least one family member (less than 65 years old) engage in farming more than 60 days is 5.08 ha.

[3] For brief summary of agriculture in Japan, see OECD (2009).

and farm road (**Figure 1**). The Japanese government is currently spending more than 12 billion dollars per year in these projects. While the primary objective of farmland consolidation is to improve productivity of individual management entities by reducing production costs[4], a regional effect on the promotion of farmland liquidization, nurturing of core farmers, and concentration of farmland to core farmers has become a major policy goal of farmland consolidation since 1992 (MAFF, 2005a). The expectation behind is that because reshaping and enlargement of plots enhances productivity, demand for farmland rental will be stimulated. Moreover, farmland consolidation physically equalizes the quality of soil and reduces asymmetric information on soil conditions of plots which makes borrowers easier to rent-in. As for lenders, physical farmland consolidation is said to mitigate psychological obsession of holding inherited farmland into one's own hand and ease hesitation against renting out (Kunimitsu, 2008:106).

The primary focus of existing studies on farmland consolidation in Japan is on its effect on management of individual farmers. Kondo (1998:ch.5) finds that high appraisal against farmland consolidations by farmers comes from its effect in saving labor costs. Kiminami and Kiminami (2005) finds that farmland consolidation contributed in raising agricultural income in Niigata prefecture. In regard to the relationship between farmland consolidation and liquidization, Kunimitsu (2008:ch.5) estimates demand and supply functions of farmland rental from farmer-level questionnaire. He concludes from the analysis that while the projects facilitates owner-cultivation of small farmers who are potential lenders, large farmers would rent-in more and as a consequence will lead into concentration of farmland into small number of core farmers. Takeya (1986) finds positive correlation between farmland readjustment and liquidization by using cross-section municipality level data from Census of Agriculture in 1980. Finally, on its own evaluation, MAFF (2005b) asserts contribution of farmland consolidation on prevention of farmland abandonment, improved labor and land productivity, rise of operation size, reduction of production cost, and concentration of farmland to core farmers. However, these evaluations do not control for other factors that affect farmland abandonment or liquidization, nor take into account for selection issues of project placement. A more careful and rigorous examination on the effect and validity of farmland consolidation with standard program evaluation framework is required.

In this paper, I examine the impact of farmland readjustment on farmland use and structural adjustment in Niigata, the second largest rice producing prefecture in Japan. Since the ratio of area

[4] According to Kawasaki (2009), efficiency will be increased and costs are reduced if the ratio of readjusted farmland exceeds 80%.

of readjusted farmland had been low, considerable progress of farmland readjustment has been made recently[5]. I use census data of rural communities for 1990 and 2000 covering all of more than 4,500 rural communities in Niigata. Given the community-level panel data for two periods, I investigate the impact of farmland readjustment with four different approaches: pooled cross-section regression, first-difference (FD), difference-in-differences (DID), and difference-in-differences propensity score matching (DID-PSM).

The main findings are summarized as follows. First, rural communities with higher proportion of readjusted farmland tend to have higher use and more transactions of farmland. Second, treatment communities that had farmland readjustment during our observation period are in relatively favorable condition in terms of gradient of farmland. Third, the results of FD, DID, and DID-PSM estimations indicate that farmland readjustment had statistically significant impact in slowing the abandonment of paddies, increasing rental of farmland, and outsourcing agricultural work. The DID-PSM estimates indicate that treatment communities had in average 1.0 to 2.4% points lower growth of ratio of abandoned farmland during 1990 to 2000 than control communities, depending on the method of matching. Treatment communities also had higher increase of rented farmland and higher growth of outsourcing. Fourth, the impact of farmland readjustment on expansion of outsourcing of farm works is larger in better-conditioned (flat gradient) communities. Moreover, we find suggestive evidence that the projects facilitated retirement of elder or small farmers and proceeded in concentration of farmland towards core farmers through rental.

The results suggest that farmland readjustment projects could be effective in promoting structural adjustment and concentrating farmland to efficient farmers. Such change would be effective in improving the efficiency of agricultural sector by inducing economies of scale which was impossible under fragmentation of small plots.

2. Data

Data is from the *Rural community card, World Census of Agriculture and Forestry 2000*. The unit of observation is rural community, which is the “smallest unit of regional society in rural villages”. The data contains information on indicators of agriculture for all rural communities for 2000 as well as past data for 1970, 75, 80, 85, 90, 95 for some major indicators. I match the *Rural community card 1990* to obtain information on farmland readjustment in 1990. Since no further information on

[5] Niigata had increased its area of readjusted paddies for 14,751 ha from 1993 to 2001, which is the highest among all prefectures. However, the ratio of area readjusted paddies in 2001 in Niigata is 50.3% which is still less than the national average of 57.4%.

farmland readjustment is available before 1990, I concentrate on 1990 and 2000.

Definition and summary statistics of the variables used for the analysis is presented in **Table 1**. The indicator of implementation of a farmland consolidation project in a community is the ratio of readjusted farmland area over total farmland area and "readjustment dummy" which takes unity if (i) the area of readjusted farmland is larger in 2000 than 1990, and (2) the ratio of readjusted farmland increased by 25% points[6] between 1990 and 2000. A rationale for using this binary readjustment dummy as well as the ratio of readjusted farmland is that the latter may not identify the implementation of a readjustment project correctly. To see this, note that the ratio of readjusted farmland can increase even if no readjustment was implemented when there was a decline of total farmland. This is a concern because farmland abandonment is increasing. On the other hand, the ratio of readjusted farmland can decrease even without readjustment when area of abandoned farmland was larger than area of readjusted farmland[7].

I focus on farmland use and farmland liquidization as an outcome of farmland readjustment. The indicators of farmland use are ratio of area of abandoned farmland, and ratio of area of planted farmland. I capture farmland liquidization by ratio of area of farmland rented-in and ratio of area of farmland rented-out that captures the extent of farmland rental. Ratio of area of farmland under various entrusted agricultural service (all work, plowing and puddling, rice planting, mowing and threshing) is also of interest because it implies concentration of farmland at the agricultural work level, which would reduce production cost and enhance efficiency of management.

3. Method

3.1. Project outcome

The outcome of interest is the average treatment effect of farmland readjustment on the treated communities. Let y_{1i} denote the indicator of outcome for community i when the community had implemented a readjustment project, y_{0i} denote the outcome when the community had not implemented a project, and D_i is a dummy variable which takes unity when a community had implemented a project and zero otherwise. The average treatment effect on the treated is then

$$ATT = E(y_{1i} - y_{0i} | D_i = 1) \quad (1)$$

The so-called evaluation problem is that one cannot observe y_{1i} and y_{0i} at the same time. I estimate ATT with four different approaches described below with each holding different

[6] This criterion is arbitrary but the results using 50% points do not make a large difference.
[7] Indeed, the ratio of readjusted farmland increased in 1,637 out of 4,681 rural communities, but in 402 communities, the area of readjusted farmland was stable or had decreased. This means that increase of the ratio of readjusted farmland was merely due to decline of total area of farmland.

assumptions on the counterfactual, y_{0i}.

Evaluation of impact of farmland readjustment in our case differs from the usual program evaluation in two points. First, the treatment is not necessary binary (i.e., treatment or control) but continuous: we can capture it by the ratio of readjusted farmland. To utilize the continuous nature of treatment, I conduct fixed-effect estimation by setting the ratio of readjusted farmland as dependent variable before proceeding to a standard binary treatment-control comparison.

Second, additional treatment is possible in our case. For example, a community with a 20% share of readjusted farmland can implement additional project to increase the ratio up to 60%. Then, it becomes hard to distinguish the long-term effect of the past treatment (20%) and the short-term effect of the additional 40%. As a matter of fact, we can expect instantaneous effects as well as long-term effects. Short-term effects of farmland liquidization are caused by the fact that a readjustment project press farmers for decision on future planning of operation and likely to prompt retirement, farmland rental, or outsourcing for elderly farmers or small part-time farmers. In addition, some projects are required to achieve certain share of farmland concentrated and managed by core farmers as condition of project implementation and this also boosts farmland rental and outsourcing. On the other hand, long-term effects would reflect lower search cost in finding borrowers since readjusted plots are easier and cost-effective to manage. Since the data at hand has only two time points, the issue of distinguishing these two effects is left for future research.

If the effect of farmland readjustment on farmland usage and liquidization lasts for longer period, then this raises another issue that our control communities that did not implement a readjustment project during our observation period are not a suitable comparison group against treatment communities that did implement a project during the same period, because many control communities in fact had their treatment in the past. The mean ratio of readjusted farmland in 1990 for control communities is 76.4%, which is 61.2% points higher compared to 15.2% for treatment communities ($p < 0.001$). Since many of the control communities had already been treated, simple comparison of the outcome variables between treatment communities and control communities would underestimate the treatment effect. I will come back to this issue later.

3.2. Estimation

I estimate ATT with the following four methods. The first method is a simple pooled regression. I pool all communities for 1990 and 2000 and regress the outcome variables on the ratio of readjusted farmland and other community characteristics:

$$y_{it} = \alpha + \beta d_{it} + \gamma x_{it} + \delta_t + \epsilon_{it} \quad (2)$$

where y_{it} is the outcome variable of community i in year t, d_{it} is the ratio of readjusted farmland, x_{it} is the vector of community characteristics, δ_t is the year fixed effect, and ϵ_{it} is the error term. Since this method only uses cross-sectional variation, the estimates would be biased when there are unobserved community differences which are not controlled for.

The second method is first-difference estimation:

$$\Delta y_i = \alpha + \beta \Delta d_i + \gamma \Delta x_i + \Delta \epsilon_i \quad (3)$$

where Δ denotes the difference between 1990 and 2000. This method utilizes the intertemporal variation within a community so time-invariant component of omitted variable bias is eliminated.

The independent variable in the above two methods is the ratio of readjusted farmland and this may not precisely capture the implementation of a readjustment project as discussed earlier. In the remaining two methods, I employ a binary treatment dummy as an indicator of project implementation.

The third method is difference-in-differences estimation. I compare changes of outcome variables from 1990 to 2000 between treatment and control communities:

$$\Delta y_i = \alpha + \beta D_i + \gamma \Delta x_i + \Delta \epsilon_i \quad (4)$$

where D_i is the treatment dummy. This is just a replacement of d_i in eq. (3) with a binary variable D_i.

As we see in detail below, placement of readjustment projects were not random but rather depended on community conditions and consent of community households. Therefore, I employ a matching estimation as the fourth method. For each treatment community, I match one or several control communities that are alike and compare the changes of the outcomes between the matched communities (Rosenbaum and Rubin, 1983; Heckman, Ichimura and Todd, 1997. For a survey on program evaluation with matching, see Todd (2008), and Caliendo and Kopeinig (2008).) I employ nearest-neighbor, kernel, and local linear matching as matching method.

4. Results

4.1. Pooled regression and first-difference estimates

Table 2 panel A presents OLS estimates of eq. (2). Data are pooled for 1990 and 2000. The dependent variables are indicators of farmland usage and liquidization, whereas the independent variables are ratio of readjusted farmland, gradient, classification of agricultural area, time distance to DID (densely inhibited district), classification of city planning area, classification of agricultural promotion area, ratio of part-time farm households, ratio of elderly farmers, number of farm households, and 2000 year dummy. We find that farmland use and liquidization are higher for communities with higher ratio of readjusted farmland; the coefficient of the ratio of readjusted farmland is negative and statistically significant at the 1% level for the ratio of abandoned farmland, while it is significantly positive for the ratio of farmland rented-out, ratio of area under agricultural service, and the ratio of large farmers. Most of the coefficients of other independent variables have the expected sign. Farmland abandonment is more frequent and large farmers are scarce in communities with adverse conditions such as steep gradient and mountainous topology. On the contrary, outsourcing is more active in communities with gentle gradient than flat communities. Communities with higher ratio of part-time farm households tend to have more outsourcing of agricultural works but the ratio of large farmers is lower. Finally, farmland usage is low in communities with higher ratio of elderly farmers.

Panel B of Table 2 presents the result of first-difference OLS estimation (or equivalently, fixed-effect estimation in the current case) described as in eq. (3). In addition to change in the ratio of readjusted farmland, I include changes in the ratio of part-time farmers, ratio of elderly farmers, and number of farm households which change over time. The second row of Panel B reports the estimates of the regression with the ratio of readjusted farmland in 1990 to control for the long-lasting impact of the past projects. The result in the third row is the estimates using samples restricted to those which the ratio of readjusted farmland was zero in 1990. Restriction of samples has a benefit of raising precision of estimates because insufficient variation of the dependent variable would increase standard errors. In our case, the ratio of readjusted farmland did not change from 1990 to 2000 in 1,694 out of 4,780 communities because all of their farmland was already fully readjusted by 1990. We can observe that the absolute value of the coefficients tend to become larger from first to third row, suggesting that the project impact is underestimated due to long-term impact of past treatment. The observed overall tendency is that communities that increased the ratio of readjusted farmland tend to increase the ratio of farmland under agricultural service (especially works such as plowing and puddling, and rice planting). Farmland rental also seems to become active with farmland readjustment.

4.2. Difference-in-differences estimates

In the analysis hereafter, I use the readjustment dummy to handle with the possible measurement error in the ratio of readjusted farmland. I also restrict samples to 1,094 communities which the ratio of readjusted farmland was zero in 1990 to avoid underestimation of project impact due to long-lasting effect of the past projects among control communities that were already treated. Even so, we still keep 61.1% of communities (496 out of 812) that implemented farmland readjustment during our observation period. With the restricted sample, I am comparing the communities with and without treatment, conditional on having zero treatment before 1990. The estimate of project impact is therefore the effect of purely new farmland readjustment implemented in previously untreated communities. Out of 1,094 communities that had no farmland readjustment before 1990, 496 communities were treated by 2000. The remaining 598 communities form the control group. A drawback of restricting samples in this way is that communities in the restricted sample tend to have steeper gradient and are located in intermediate or mountainous agricultural area compared to communities that had some farmland readjustment before 1990[8]. I will comment on the implication that arises from this sampling bias in section 5.

The OLS estimates of difference-in-differences estimation are presented in **Panel A and B of Table 3**. Results in Panel A are derived from regression with readjustment dummy as the only explanatory variable. So, the coefficient of readjusted dummy is the raw difference of mean changes of outcomes between treated communities and control communities. The coefficient is statistically significant and negative for ratio of abandoned farmland and positive for ratio of area rented-out and ratios of area under agricultural service (plowing and puddling, and rice planting).

Figure 2 graphically depicts the mean of outcomes for treatment and control groups in 1990 and 2000. Farmland usage is getting worse in both of ratio of abandoned farmland and ratio of area planted. Even though no farmland readjustment was yet implemented, the ratio of abandoned farmland was lower for treatment group than control group in 1990. Farmland abandonment is proceeding even in treatment communities as well, but the pace is slower than control group. By contrary, ratio of panted area was initially lower for treatment group and it is getting worse after farmland readjustment. Farmland rental is expanding throughout the observation period but the range of increase for treatment group is greater than control group, especially for ratio of area rented-out. Outsourcing of agricultural work is also growing. Initially, treatment group had higher ratio of area under agricultural service for all works. The figure for treatment group is rising after farmland readjustment where, depending on the contracted work, the change is 0.8 to 2.4% points greater than control group.

While Panel A of Table 3 and Figure 1 did not control for other variables, Panel B reports estimate with time-variant variables (ratio of part-time farmers, ratio of elderly farmers, number of farm households) as controls. The results are mostly similar to that in Panel A.

4.3. Matching estimates

The results so far suggest positive effects of farmland readjustment on farmland usage and liquidization. However, the relationships may not be causal since placement of farmland readjustment project may have been prioritized to communities with higher potential of farmland

[8] The percentage of communities with steep gradient is 41.4% for communities with no farmland readjustment by 1990 and 11.0% for communities that had some farmland readjustment before 1990. The same figure for being an intermediate agricultural area is 53.9% and 34.5%, and the percentage of mountainous agricultural area communities is 14.3% and 9.0% ($p < 0.001$ for all comparisons).

usage or potential of liquidization. To investigate the possibility of selection on project placement, I compare the mean differences of farmland usage, liquidization, and other community characteristics in 1990 between treatment and control group in **Table 4**. The table indicates that, prior to treatment, treatment communities had in average, higher level of farmland usage and liquidization than control communities. The ratio of abandoned farmland in 1990 for treatment group is 4.8%, which is 6.1% point lower than control group ($p < 0.001$). With regard to farmland abandonment, treatment communities tend to had effective use of farmland even before farmland readjustment was implemented[9]. As for farmland liquidization, although the differences are at most 1.4% points, ratio of area rented-out and figures of ratio of area under agricultural service (except "all work") for treatment group are greater than control group and are statistically significant. The ratio of large farmers is also higher for treatment group (the difference is 13.4% points). By comparing the community characteristics, we find that treatment communities are in favorable conditions with gentler gradient, more likely to be in flat agricultural area, and close to DID. These tendencies are reconfirmed in **Table 5** which shows the treatment rate by communities with different gradient and classification of agricultural area.

These observations suggest that treatment communities had higher level of farmland usage and liquidization even before treatment. Treatment communities are also in favorable conditions. The estimated project impact will be biased if such community conditions or level of farmland usage or liquidization before treatment was correlated with project placement. Therefore, I proceed to difference-in-differences matching estimation with application of nearest-neighbor, kernel, and local linear matching.

The variables used for matching is the community characteristics and the outcome variables in 1990 (before treatment). Propensity score for kernel and local linear matching are estimated by probit. Estimates of marginal effects evaluated at the mean of each independent variable are reported in **Table 6**. Column 1 reports estimates using community characteristics, whereas column 2 adds nine outcome variables in 1990. Communities with steeper slope or located faraway from DID have lower probability of getting treated, while agricultural promotion area attracts readjustment project. Communities that were already stagnant in farmland usage in 1990 were less likely to be treated, whereas communities with more farmland rental or entrusted agricultural work and higher ratio of large farmers had higher probability of implementing a project. These results confirm that readjustment projects were placed in communities with relatively favorable condition and had active farmland rental or outsourcing of agricultural work. The choice of set of independent variables did not affect the results of the following analysis, so I report results with matching based on column 2.

Following Abadie and Imbens (2002), I match four control communities that are most alike

[9] However, ratio of area planted for treatment group is 0.7% points lower than control group.

against each treatment community with nearest-neighbor matching[10]. Standard errors are Abadie and Imbens (2002)'s variance estimator. I also report results with matching by bias-corrected estimator proposed in Abadie and Imbens (2002). Epanechnikov kernel is used for kernel matching. The bandwidth is set to 0.6 for kernel and local linear matching[11]. Standard errors are obtained by boostrapping with 50 repetitions. Samples are restricted to communities that suffice common support.

I check balancing by estimating the "treatment effect" of readjustment dummy for outcomes before treatment (in 1990) and community characteristics. **Table 7** indicates that nearest-neighbor and kernel matching are not very successful in balancing the treatment and control communities while bias-corrected nearest neighbor and local linear matching seem to do well.

Matching estimates of ATT of readjustment project are reported in **Panel C of Table 3**. The sign of the coefficients of readjustment dummy did not change regardless of method used for matching, but some statistical significance did vary with different methods. The ATT is positive and statistically significant for the ratio of area under agricultural service (plowing and puddling) and it is robust to choice of matching methods. The estimates indicate a 2.4 to 3.1% points increase of the ratio due to farmland readjustment. The coefficient of readjustment dummy is negative and statistically significant for three out of four matching methods for ratio of abandoned farmland, suggesting that the project slowed down the deterioration of farmland usage. Ratio of area rented-out and ratio of area under agricultural service (rice planting) also seem to have increased due to farmland readjustment.

The magnitude and statistical significance of the coefficients suggest that farmland readjustment promotes outsourcing of agricultural work rather than farmland rental. Improvement of farming conditions by readjustment may facilitate owner-cultivation which is indicated by Kondo (1998) or Kunimitsu (2008: ch.5). The expansion of outsourcing can be explained consistently if farmers are adopting sourcing in order to reduce production cost under owner-cultivation.

In summary, the results show a consistent overall tendency that farmland readjustment had loosened the declining trend of farmland abandonment, while it expanded farmland rental and outsourcing of agricultural works. However, the estimated ATT is not so large with at most 3% points difference between treatment and control group. One worrisome result that has been consistently observed throughout the analyses is that although statistically insignificant, treatment group tend to decrease the rate of area planted more than control group. A possible explanation is that farmland readjustment fostered selection of plots to cultivate and plots to abandon[12].

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[10] The estimation is conducted by "nnmatch" command for Stata.
[11] Bandwidth of 0.02, 0.4, 0.8 were tried but the results did not differ qualitatively.
[12] I thank the members of Farmland Department of Niigata prefecture for suggesting this.

4.4. Heterogenous effects

As a final exercise, I examine whether the impact of farmland readjustment differ with community conditions. To do so, I regress the following model which adds interaction term of readjustment dummy and gradient or classification of agricultural area:

$$\Delta y_i = \alpha + \beta_1 D_i + \beta_2 D_i z_i + \beta_3 z_i + \gamma \Delta x_i + \Delta \epsilon_i \quad (5)$$

where z_i is a dummy of gradient or classification of agricultural community. Change of time-variant controls (ratio of part-time farmers, ratio of elderly farmers, and number of farm households) are also included as independent variables.

The results are reported in **Table 8**. Panel A reveals that the positive impact of farmland readjustment is significantly smaller in gradient communities than flat communities but ATT on ratio of large farmers is larger. Panel B confirms the same trend using interaction with classification of agricultural area. These results suggest that the effect of farmland readjustment is more likely to be realized under favorable conditions. However, ATT on the ratio of area rented-in is greatest in mountainous agricultural area. Although not precisely estimated, greater impact is observed for ratio of large farmers in relatively adverse communities. This may suggest that farmland readjustment facilitates the structural change through retirement of small farmers and consolidation to core farmers rather than through expansion of farmland rental or outsourcing of agricultural works.

5. Conclusion

In this paper, I investigated the impact of farmland readjustment on farmland usage and liquidization. The results of pooled regression, first-difference, difference-in-differences, and matching estimates indicate that farmland readjustment alleviated the progress of farmland abandonment and facilitated outsourcing of agricultural works. It is also likely that the projects expanded farmland rental. Therefore, I conclude that farmland readjustment has positive effects on farmland usage and liquidization.

Two remarks should be noted. First, since we focused on communities that never had farmland readjustment before 1990, the estimates are likely to be upper limit. However, our samples are biased to include more communities that are in relatively unfavorable conditions. Thus our estimates should be smaller than the impact for communities in average conditions. Second, since we are asking whether a community had implemented a readjustment project between 1990 and 2000, there is a maximum of nine years lag for the elapsed years after treatment. Therefore, we are treating the effect of project that completed in 1991 and 1999 equally.

The experience in Niigata suggests that farmland readjustment may also be helpful in other countries in alleviating farmland fragmentation and to promote structural adjustment and improving agricultural productivity. However, these projects tend to be quite expensive. Rigorous cost-benefit analysis should be conducted prior to implementation. The results of heterogenous effects may suggest selective use of resources to areas under favorable conditions. Finally, since farmland readjustment would facilitate liquidization and concentration of farmland to few large farmers, care should be taken on the possible adverse effect on small farmers and agricultural laborers.

References

Abadie, Alberto, and Guido Imbens (2002) “Simple and bias-corrected matching estimator for average treatment effects”, NBER Technical Working Paper, No. 283.

Bizimana, C., W. L. Nieuwoudt., and S. R. D. Ferrer (2004) “Farm size, land fragmentation and economic efficiency in Southern Rwanda”. *Agrekon*. 43(2):244-262.

Caliendo, Marco, and Sabine Kopeinig (2008) “Some practical guidance for the implementation of propensity score matching”. *Journal of Economic Surveys*, 22(1):33-72.

Chen, Zhuo., Wallace E. Huffman and Scott Rozelle (2009) “Farm technology and technical efficiency: Evidence from four regions in China” *China Economic Review*. 20(2):153-161.

Heckman, J., Ichimura, H., Todd, P. (1997) “Matching as an econometric evaluation estimator: evidence from evaluating a job training programme”, *Review of Economic Studies*. 64(4):605-654.

Heston, Alan., and Dharma Kumar (1983) “The Persistence of Land Fragmentation in Peasant Agriculture: An Analysis of South Asian Cases”, *Explorations in Economic History*. 20(2):199-220.

Hung, Pham Van., T. Gordon MacAulay., and Sally P. Marsh (2007) “The economics of land fragmentation in the north of Vietnam”. *Australian Journal of Agricultural and Resource Economics.* 51(2):195-211.

Jabarin, Amer S., and Francis M. Epplin (1994) “Impacts of land fragmentation on the cost of producing wheat in the rain-fed region of northern Jordan” *Agricultural Economics*. 11(2-3):191-196.

Kawasaki, Kentaro (2009) “The Impact of Land Fragmentation on Rice Production Cost and Factor Demands” *Journal of Rural Economics*, 81(1):14-24. (in Japanese)

Kiminami, Akira., and Lily Y. Kiminami (2005) “Panel Data Analysis on Economic Effects of Land Improvement” *Studies in Regional Science*, 35(2):415-425. (in Japanese)

Kondo, Takumi (1998) *Kihon ho nosei ka no nihon inasaku*, Hokkaido University Press: Sapporo. (in Japanese)

Kunimitsu, Yoji (2008) *Noson kokyo jigyo no keizai hyoka*, Nori Tokei Kyokai: Tokyo. (in Japanese)

Lerman, Zvi., and Dragos Cimpoies (2006) “Land Consolidation as a Factor for Rural Development in Moldova”. *Europe-Asia Studies*. 58(3):439-455.

Niroula, Gajendra S., and Gopal B. Thapa (2005) “Impacts and causes of land fragmentation, and lessons learned from land consolidation in South Asia”. Land Use Policy. 22(4):358-372.

Ministry of Agriculture, Forestry, and Fisheries (2008) *Annual Report on Food, Agriculture and Rural Areas in Japan FY 2007*.
http://www.maff.go.jp/e/annual_report/2007/index.html. (in Japanese)

Ministry of Agriculture, Forestry, and Fisheries (2005a) “Shiryo 2: Keieitai ikusei kiban seibi jigyo”
http://www.maff.go.jp/j/study/other/seibi_zissi/h17_01/pdf/data2.pdf. (in Japanese)

Ministry of Agriculture, Forestry, and Fisheries (2005b) “Tochi kairyo jigyo no koka”
http://www.maff.go.jp/nouson/jikeika/sougou_hyouka.pdf. (in Japanese)

Nugyen, Tin., Enjiang Cheng., and Christopher Findlay (1996) “Land fragmentation and farm productivity in China in the 1990s” *China Economic Review*. 7(2):169-180.

Pasakarnis, Giedrius., and Vida Maliene (2010) “Towards sustainable rural development in Central and Eastern Europe: Applying land consolidation”. *Land Use Policy* 27(2): 545-549.

Rahman, Sanzidur., and Mizanur Rahman (2008) “Impact of land fragmentation and resource ownership on productivity and efficiency: The case of rice producers in Bangladesh”. *Land Use Policy*. 26(1):95-103.

Ram, K. Anantha., A. Tsunekawa., D. K. Sahad., and T. Miyazaki (1999) “Subdivision and fragmentation of land holdings and their implication in desertification in the Thar Desert, India”. *Journal of Arid Environments*. 41(4):463-477.

Rosembaum Paul, and Donald Rubin (1983) “The Central Role of the Propensity Score in Observational Studies for Causal Effects”. *Biometica*. 70:41-55.

Takeya, hiroyuki (1986) “Hojo seibi to seisan soshikika, kengyo nogyo saihen” in Misono, Yoshihiro eds *Kengyo nogyo no saihen.* Ochanomizu shobo: Tokyo. (in japanese)

Tan, Shuhao., Nico Heernik., and Futian Qu (2006) “Land fragmentation and its driving forces in China”. *Land Use Policy*. 23(3):272-285.

Thomas, Joachim (2006) “Property rights, land fragmentation and emerging structure of agriculture in Central and Eastern European countries”. *Electronic Journal of Agricultural and Development Economics*. 3(2):225-275.

Sikor, Thomas., Daniel Muller., and Johannes Stahl (2009) “Land Fragmentation and Cropland Abandonment in Albania: Implications for the Role of State and Community in Post-Socialist Land Consolidation”. *World Development*. 37(8):1411-1423.

Todd, Petra E., (2008) “Evaluating social programs with endogenous program placement and selection of the treated”, *Handbook of Development Economics*, Volume 4, pp.3847-3894.

van Dijk, Terry (2007) “Complications for traditional land consolidation in Central Europe”, *Geoforum*. 38(3):505-511.

Vitikainen, Arvo (2004) “An Overview of Land Consolidation in Europe”, *Nordic Journal of Surveying and Real Estate Research*. 1(1):25-44.

Wan, Guang H., and Enjiang Cheng (2001) “Effects of land fragmentation and returns to scale in the Chinese farming sector” *Applied Economics*. 33(2):183-194.

Table 1. Summary statistics of variables

Variable	Definition	Remark	1990 Mean	1990 S.D.	2000 Mean	2000 S.D.
Ratio of readjusted farmland	Area of readjusted farmland/Area of farmland	Paddy, area-based	0.654	0.423	0.766	0.368
Readjustment dummy	Dummy, 1 if (i) the area of readjusted farmland increased between 1990 and 2000, and (ii) the ratio of readjusted farmland increased more than 25 % points. 0 otherwise.	Paddy, area-based			0.171	
Ratio of abandoned farmland	Area of abandoned farmland/(Area of owned farmland + area of abandoned farmland)	Paddy and upland field	0.044	0.082	0.056	0.085
Ratio of area planted	(Area of owned farmland - area without any crops)/Area of owned farmland	Paddy	0.969	0.055	0.901	0.090
Ratio of area rented-in	Area of farmland rented-in/area of farmland under management	Paddy	0.117	0.104	0.187	0.143
Ratio of area rented-out	Area of farmland rented-out/area of owned farmland	Paddy	0.039	0.068	0.046	0.079
Ratio of area under agricultural service (all work)	Area accepting entrusted agricultural work (all work)/area of farmland under management	Paddy	0.012	0.066	0.014	0.116
Ratio of area under agricultural service (plowing and puddling)	Area accepting entrusted agricultural work (plowing and puddling)/area of farmland under management	Paddy	0.036	0.099	0.043	0.147
Ratio of area under agricultural service (rice planting)	Area accepting entrusted agricultural work (rice planting)/area of farmland under management	Paddy	0.031	0.086	0.045	0.124
Ratio of area under agricultural service (mowing and threshing)	Area accepting entrusted agricultural work (mowing and threshing)/area of farmland under management	Paddy	0.049	0.110	0.064	0.168
Ratio of large farmers	Number of farm households managing more than 2 ha/total number of farm households		0.211	0.244	0.242	0.259
Gradient (flat)	Dummy, 1 if the gradient is smaller than 1/100, 0 otherwise	Paddy			0.529	
Gradient (gentle)	Dummy, 1 if the gradient is 1/100 to 1/20, 0 otherwise	Paddy			0.287	
Gradient (steep)	Dummy, 1 if the gradient is greater than 1/20, 0 otherwise	Paddy			0.184	
Agricultural area (urban)	Dummy, 1 if the classification of agricultural area is urban area, 0 otherwise				0.140	
Agricultural area (flat)	Dummy, 1 if the classification of agricultural area is flat agricultural area, 0 otherwise				0.370	
Agricultural area (intermediate)	Dummy 1 if the classification of agricultural area is intermediate agricultural area, 0 otherwise				0.385	
Agricultural area (mountainous)	Dummy, 1 if the classification of agricultural area is mountainous agricultural area, 0 otherwise				0.105	
Distance to DID (0.5 to 1 hr)	Dummy, 1 if the time distance to densely inhibited district (by old city/town/village) is 0.5 to 1 hour, 0 otherwise				0.178	
Distance to DID (1 to 1.5 hr)	Dummy, 1 if the time distance to densely inhibited district (by old city/town/village) is 1 to 1.5 hour, 0 otherwise				0.047	
Distance to DID (more than 1.5 hr)	Dummy, 1 if the time distance to densely inhibited district (by old city/town/village) is more than 1.5 hour, 0 otherwise				0.003	
City planning area (Urbanizaton promotion area)	Dummy, 1 if the city planning area is "urbanization promotion area", 0 otherwise				0.021	
City planning area (Urbanizaton control area)	Dummy, 1 if the city planning area is "urbanization control area", 0 otherwise				0.231	
City planning area (not designated)	Dummy, 1 if the community is in city planning area but not designated as either urbanization promotion area or urbanization control area, 0 otherwise				0.336	
Agricultural promotion area	Dummy, 1 if the community is in agricultural promotion area, 0 otherwise				0.075	
Agricultural promotion area (farmland)	Dummy, 1 if the community is in agricultural promotion area and designated as farmland area, 0 otherwise				0.891	
Ratio of part-time farmers	Number of part-time farm households/total number of farm households		0.922	0.114	0.891	0.140
Ratio of elderly farmers	population engaged in farming above 65 years old/total population engaged in farming	Male and female	0.364	0.165	0.577	0.178
Nuber of farm households	Total number of farm households		23.686	18.892	18.869	15.682

Notes: Figures are aggregate of management level data in each community, except for ratio of readjusted farmland, derived from area based data and gradient, agricultural area, distance to DID, city planning area, agricultural promotion area are community level data. Planted crops for "ratio of area planted" includes wheat or soybeans and is not restricted to rice.

Table 2. Pooled regression and first-difference estimates

					Ratio of area under agricultural service				
	Ratio of abandoned farmland	Ratio of area planted	Ratio of area rent-in	Ratio of area rent-out	All work	Plowing and puddling	Rice planting	Mowing and threshing	Ratio of large farmers
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. Pooled regression (OLS, 1990 and 2000)									
Ratio of readjusted area	-0.034	-0.001	0.011	0.009	0.008	0.035	0.029	0.044	0.066
	(0.003)***	(0.002)	(0.009)	(0.002)***	(0.002)***	(0.003)***	(0.003)***	(0.005)***	(0.005)***
Gradient (gentle)	0.011	-0.009	-0.010	0.000	0.009	0.029	0.023	0.036	-0.132
	(0.002)***	(0.002)***	(0.009)	(0.002)	(0.004)**	(0.004)***	(0.004)***	(0.004)***	(0.005)***
Gradient (steep)	0.054	0.000	-0.033	-0.005	0.002	0.012	-0.004	0.009	-0.127
	(0.003)***	(0.003)	(0.011)***	(0.002)**	(0.003)	(0.004)***	(0.004)	(0.007)	(0.006)***
Agricultural area (urbanized area)	0.002	0.001	-0.015	-0.001	-0.006	-0.005	-0.011	-0.011	-0.068
	(0.002)	(0.002)	(0.011)	(0.002)	(0.003)**	(0.004)	(0.003)***	(0.004)**	(0.009)***
Agricultural area (intermediate)	0.023	-0.003	0.006	0.002	-0.003	-0.002	0.000	-0.002	-0.147
	(0.002)***	(0.002)	(0.009)	(0.002)	(0.003)	(0.004)	(0.004)	(0.004)	(0.005)***
Agricultural area (mountainous)	0.033	-0.001	0.013	0.001	-0.001	0.006	0.006	0.010	-0.182
	(0.004)***	(0.003)	(0.013)	(0.002)	(0.004)	(0.006)	(0.006)	(0.006)	(0.006)***
Distance to DID (0.5 to 1 hr)	0.003	0.019	-0.000	-0.007	-0.001	-0.007	-0.006	-0.009	0.011
	(0.003)	(0.002)***	(0.008)	(0.002)***	(0.002)	(0.003)**	(0.003)**	(0.004)**	(0.005)**
Distance to DID (1 to 1.5 hr)	0.006	0.023	-0.014	-0.009	-0.001	0.017	-0.000	0.011	-0.018
	(0.006)	(0.003)***	(0.015)	(0.003)***	(0.003)	(0.009)*	(0.006)	(0.008)	(0.008)**
Distance to DID (more than 1.5 hr)	0.070	0.042	0.036	-0.013	0.020	0.013	0.023	0.026	-0.029
	(0.037)*	(0.009)***	(0.054)	(0.019)	(0.017)	(0.026)	(0.023)	(0.027)	(0.024)
City planning area	-0.031	-0.020	-0.042	-0.002	0.001	-0.054	-0.024	-0.067	0.017
(Urbanizaton promotion area)	(0.007)***	(0.009)**	(0.025)*	(0.009)	(0.004)	(0.028)*	(0.008)***	(0.030)**	(0.022)
City planning area	-0.007	-0.002	-0.027	-0.010	0.001	-0.025	-0.019	-0.024	0.031
(Urbanizaton control area)	(0.002)***	(0.002)	(0.009)***	(0.002)***	(0.003)	(0.004)***	(0.003)***	(0.004)***	(0.007)***
City planning area	-0.013	0.003	-0.041	-0.009	0.004	-0.018	-0.010	-0.013	0.026
(not designated)	(0.002)***	(0.002)	(0.007)***	(0.002)***	(0.002)	(0.003)***	(0.003)***	(0.004)***	(0.005)***
Agricultural promotion area	-0.003	0.008	0.051	-0.010	-0.006	-0.010	0.014	-0.020	0.045
	(0.009)	(0.007)	(0.024)**	(0.007)	(0.004)	(0.031)	(0.009)	(0.032)	(0.016)***
Agricultural promotion area (farmland)	-0.019	-0.002	0.073	-0.013	-0.002	-0.032	-0.005	-0.036	0.091
	(0.008)**	(0.006)	(0.019)***	(0.006)**	(0.004)	(0.030)	(0.007)	(0.032)	(0.015)***
Ratio of part-time farmers	-0.031	-0.039	-0.127	-0.036	-0.008	0.027	0.035	0.045	-0.070
	(0.010)***	(0.008)***	(0.044)***	(0.007)***	(0.012)	(0.011)**	(0.008)***	(0.009)***	(0.019)***
Ratio of elderly farmers	0.020	-0.022	-0.185	0.013	-0.010	0.008	0.001	-0.002	-0.328
	(0.006)***	(0.006)***	(0.022)***	(0.005)**	(0.007)	(0.008)	(0.006)	(0.008)	(0.014)***
Nuber of farm households	-0.000	-0.000	-0.001	-0.000	-0.000	0.000	0.000	0.000	-0.000
	(0.000)***	(0.000)***	(0.000)***	(0.000)**	(0.000)	(0.000)***	(0.000)***	(0.000)***	(0.000)*
Year 2000 dummy	0.011	-0.065	0.154	0.000	0.002	0.005	0.013	0.014	0.089
	(0.002)***	(0.002)***	(0.008)***	(0.002)	(0.003)	(0.003)*	(0.003)***	(0.004)***	(0.005)***
Constant	0.088	1.018	0.308	0.082	0.020	0.012	-0.019	0.005	0.402
	(0.012)***	(0.010)***	(0.048)***	(0.009)***	(0.014)	(0.030)	(0.011)*	(0.031)	(0.025)***
Observations	9384	9383	9382	9382	9383	9383	9383	9383	9385
Adjusted R^2	0.30	0.21	0.08	0.02	0.00	0.03	0.04	0.04	0.43
B. First-difference estimation (coefficient of ratio of readjusted farmland)									
Full sample, without initial value	0.002	0.000	-0.004	0.000	0.010	0.021	0.012	0.007	-0.004
	(0.003)	(0.005)	(0.005)	(0.003)	(0.010)	(0.008)***	(0.006)**	(0.007)	(0.005)
Full sample, with initial value	-0.008	-0.009	0.014	0.005	0.010	0.017	0.012	0.006	0.011
	(0.005)	(0.005)*	(0.006)**	(0.004)	(0.009)	(0.008)**	(0.006)*	(0.007)	(0.005)**
Restricted sample, without initial value	-0.014	-0.011	0.015	0.011	0.019	0.027	0.015	0.011	0.009
	(0.007)**	(0.007)	(0.008)*	(0.005)**	(0.015)	(0.010)***	(0.008)*	(0.010)	(0.007)

Notes: *, **, ***, indicate statistical significant at 10%;, 5%; and 1%. 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 controls for change in time-variant community characteristics (ratio of part-time farmers, ratio of elderly farmers, number of farm households. "with initial value" indicates that the 1990 value of ratio of readjusted farmland is included as independent variable. "Restricted samples" refer to communities with zero ratio of readjusted farmland in 1990.

Table 3. Difference-in-differences and matching estimates

	Ratio of abandoned farmland	Ratio of area planted	Ratio of area rent-in	Ratio of area rent-out	Ratio of area under agricultural service				Ratio of large farmers
					All work	Plowing and puddling	Rice planting	Mowing and threshing	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. DID (OLS, raw difference)									
Readjustment dummy	-0.012	-0.010	0.007	0.010	0.014	0.024	0.011	0.008	0.007
	(0.007)*	(0.006)	(0.007)	(0.004)**	(0.012)	(0.009)***	(0.007)*	(0.008)	(0.006)
Constant	0.025	-0.060	0.057	-0.002	-0.000	0.003	0.012	0.012	0.017
	(0.005)***	(0.004)***	(0.005)***	(0.002)	(0.002)	(0.003)	(0.003)***	(0.005)**	(0.003)***
Time-variant controls?	No	No	No	No	No	No	No	No	No
Observations	1073	1072	1072	1071	1072	1072	1072	1072	1073
Adjusted R^2	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00
B. DID（OLS, with time-variant community characteristics)									
Readjusted dummy	-0.012	-0.008	0.011	0.010	0.014	0.023	0.011	0.008	0.008
	(0.006)*	(0.006)	(0.007)	(0.004)**	(0.012)	(0.009)***	(0.007)*	(0.008)	(0.006)
Constant	0.018	-0.067	0.050	-0.004	0.002	0.001	0.014	0.006	0.012
	(0.007)**	(0.006)***	(0.009)***	(0.004)	(0.004)	(0.006)	(0.005)***	(0.007)	(0.006)*
Time-variant controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1064	1063	1063	1063	1063	1063	1063	1063	1064
Adjusted R^2	0.01	0.02	0.02	0.02	0.00	0.01	0.01	0.00	0.01
C. DID-matching estimates (ATT of farmland readjustment)									
Nearest neighbor	-0.024	-0.003	0.009	0.005	0.012	0.025	0.015	0.012	-0.003
	(0.008)***	(0.008)	(0.008)	(0.004)	(0.010)	(0.007)***	(0.006)**	(0.007)*	(0.008)
Nearest neighbor (bias-corrected)	-0.013	-0.009	0.003	0.013	0.011	0.031	0.014	0.017	-0.016
	(0.008)*	(0.008)	(0.008)	(0.004)***	(0.010)	(0.007)***	(0.006)**	(0.007)**	(0.008)**
Kernel	-0.017	-0.007	0.006	0.011	0.002	0.024	0.012	0.011	0.005
	(0.005)***	(0.006)	(0.009)	(0.004)***	(0.007)	(0.010)**	(0.007)	(0.010)	(0.006)
Local linear	-0.010	-0.013	0.003	0.017	0.000	0.030	0.021	0.017	-0.002
	(0.008)	(0.006)**	(0.009)	(0.005)***	(0.011)	(0.008)***	(0.011)*	(0.011)	(0.010)

Notes: *, **, ***, indicate statistical significant at 10%;, 5%; and 1%. Robust standard error reported in parenthesis. Time-variant community characteristics controlled in Panel B are ratio of part-time farmers, ratio of elderly farmers, and number of farm households. Samples in the matching estimates in Panel C are restricted to those that suffice common support. Four control communities are matched for nearest neighbor matching. Standard error for nearest neighbor matching is the variance estimator suggested by Abadie and Imbens (2002). Standard errors for kernel and local linear matching are obtained from bootstrapping with 50 repetitions.

Table 4. Comparison of pre-treatment values between treatment and control groups

	Treatment (N=496)	Control (N=598)	Difference	*p* value	
Indicators of farmalnd usage and liquidization					
Ratio of abandoned farmland	0.048	0.109	-0.061	0.000	***
Ratio of area planted	0.969	0.976	-0.007	0.012	***
Ratio of area rented-in	0.119	0.112	0.007	0.298	
Ratio of area rented-out	0.038	0.033	0.005	0.124	
Ratio of area under agricultural service (all work)	0.008	0.006	0.002	0.203	
Ratio of area under agricultural service (plowing and puddling)	0.025	0.017	0.008	0.087	*
Ratio of area under agricultural service (rice planting)	0.020	0.010	0.011	0.000	***
Ratio of area under agricultural service (mowing and threshing)	0.035	0.021	0.014	0.010	**
Ratio of large farmers	0.190	0.056	0.134	0.000	***
Community characteristics					
Gradient (gentle)	0.270	0.278	-0.008	0.761	
Gradient (steep)	0.224	0.574	-0.350	0.000	***
Agricultural area (urban)	0.147	0.067	0.080	0.000	***
Agricultural area (intermediate)	0.421	0.661	-0.239	0.000	***
Agricultural area (mountainous)	0.099	0.182	-0.083	0.000	***
Distance to DID (0.5 to 1 hr)	0.202	0.380	-0.178	0.000	***
Distance to DID (1 to 1.5 hr)	0.046	0.107	-0.061	0.000	***
Distance to DID (more than 1.5 hr)	0.002	0.003	-0.001	0.676	
City planning area (Urbanizaton promotion area)	0.020	0.005	0.015	0.021	**
City planning area (Urbanizaton control area)	0.228	0.085	0.143	0.000	***
City planning area (not designated)	0.286	0.259	0.027	0.316	
Agricultural promotion area	0.145	0.162	-0.017	0.438	
Agricultural promotion area (farmland)	0.819	0.786	0.033	0.179	
Ratio of part-time farmers	0.924	0.896	0.028	0.000	***
Ratio of elderly farmers	0.371	0.391	-0.020	0.048	**
Nuber of farm households	22.442	17.333	5.109	0.000	***

Table 5. Treatment rates by community conditions

	Gradient				Agricultural area				
	Flat	Gentle	Steep	Total	Urban	Flat	Inter mediate	Moun tainous	Total
Treatment	87	164	338	589	40	54	395	109	598
Control	251	134	111	496	73	165	209	49	496
Total	338	298	449	1,085	113	219	604	158	1,094
Treatment rate	0.743	0.450	0.247	0.457	0.646	0.753	0.346	0.310	0.453

Note: "treatment" indicate that a community had implemented farmland readjustment during 1990 to 2000.
"Treatment rate" is the ratio of treated communities over total number of communities.

Table 6. Probit estimates of project placement (marginal effects)

	(1)	(2)
Gradient (gentle)	-0.204	-0.175
	(0.044)***	(0.047)***
Gradient (steep)	-0.396	-0.325
	(0.043)***	(0.048)***
Agricultural area (urban)	0.006	0.111
	(0.072)	(0.078)
Agricultural area (intermediate)	-0.186	-0.075
	(0.051)***	(0.057)
Agricultural area (mountainous)	-0.189	-0.053
	(0.059)***	(0.071)
Distance to DID (0.5 to 1 hr)	-0.102	-0.110
	(0.040)**	(0.042)***
Distance to DID (1 to 1.5 hr)	-0.160	-0.166
	(0.061)***	(0.062)***
Distance to DID (more than 1.5 hr)	-0.060	0.032
	(0.285)	(0.314)
City planning area	0.428	0.363
(Urbanizaton promotion area)	(0.119)***	(0.154)**
City planning area	-0.078	-0.122
(Urbanizaton control area)	(0.060)	(0.062)*
City planning area	-0.052	-0.049
(not designated)	(0.043)	(0.044)
Agricultural promotion area	0.357	0.365
	(0.093)***	(0.092)***
Agricultural promotion area	0.375	0.356
(farmland)	(0.078)***	(0.084)***
Ratio of part-time farmers	0.200	0.172
	(0.141)	(0.147)
Ratio of elderly farmers	-0.114	-0.009
	(0.101)	(0.106)
Number of farm households	0.003	0.002
	(0.001)**	(0.001)*
Ratio of abandoned farmland		-0.484
		(0.186)***
Ratio of area planted		-0.623
		(0.362)*
Ratio of area rent-in		0.181
		(0.167)
Ratio of area rent-out		0.701
		(0.329)**
Ratio of area under agricultural service		-0.332
(all work)		(0.569)
Ratio of area under agricultural service		0.756
(plowing and puddling)		(0.381)**
Ratio of area under agricultural service		0.249
(rice planting)		(0.455)
Ratio of area under agricultural service		-0.044
(mowing and threshing)		(0.234)
Ratio of large farmers		0.663
		(0.138)***
Observations	1077	1076
	LR Chi2(16)=263.21	LR Chi2(25)=318.74
Prob > chi2	0.000	0.000
Pseudo R^2	0.1771	0.2146
Log likelihood	-611.55557	-583.1756

Note: *, **, ***, inidicate statistical significant at 10%;, 5%; and 1%. Standard error reported in parenthesis. Coefficients are marginal effects evaluated at the mean.

Table 7. Balancing test after matching

	Matching method							
	Nearest neighbor		Nearest neighbor (bias-corrected)		Kernel (bandwidth=0.6)		Local linear (bandwidth=0.6)	
Dependent variable (pre-treatment values in 1990)	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Ratio of abandoned farmland	-0.018	(0.004)***	0.000	(0.004)	-0.035	(0.003)***	-0.013	(0.004)***
Ratio of area planted	-0.009	(0.002)***	0.000	(0.002)	-0.003	(0.002)	0.002	(0.003)
Ratio of area rented-in	0.016	(0.006)***	-0.000	(0.006)	0.001	(0.003)	-0.011	(0.010)
Ratio of area rented-out	0.011	(0.002)***	-0.000	(0.002)	0.002	(0.002)	0.001	(0.003)
Ratio of area under agricultural service (all work)	0.004	(0.001)***	-0.000	(0.001)	0.002	(0.001)	0.003	(0.001)*
Ratio of area under agricultural service (plowing and puddling)	0.010	(0.002)***	-0.000	(0.002)	0.005	(0.002)**	-0.001	(0.004)
Ratio of area under agricultural service (rice planting)	0.010	(0.002)***	-0.000	(0.002)	0.006	(0.002)***	0.001	(0.004)
Ratio of area under agricultural service (mowing and threshing)	0.018	(0.003)***	-0.000	(0.003)	0.010	(0.003)***	0.007	(0.005)
Ratio of large farmers	0.095	(0.010)***	0.000	(0.010)	0.092	(0.024)***	-0.009	(0.017)
Gradient (gentle)	-0.049	(0.025)**	0.000	(0.025)	-0.052	(0.029)*	0.027	(0.033)
Gradient (steep)	-0.113	(0.021)***	0.000	(0.021)	-0.193	(0.011)***	-0.020	(0.016)
Agricultural area (flat)	0.011	(0.005)**	0.000	(0.005)	0.060	(0.013)***	0.028	(0.024)
Agricultural area (intermediate)	-0.104	(0.022)***	-0.000	(0.022)	-0.184	(0.029)***	0.007	(0.033)
Agricultural area (mountainous)	0.011	(0.005)**	0.000	(0.005)	-0.045	(0.010)***	-0.003	(0.017)
Distance to DID (0.5 to 1 hr)	-0.029	(0.010)***	0.000	(0.010)	-0.109	(0.014)***	0.017	(0.023)
Distance to DID (1 to 1.5 hr)	-0.002	(0.001)	0.000	(0.001)	-0.033	(0.006)***	-0.019	(0.015)
Distance to DID (more than 1.5 hr)	0.001	(0.001)	0.000	(0.001)	-0.001	(0.001)	0.001	(0.003)
City planning area (Urbanizaton promotion area)	0.015	(0.002)***	-0.000	(0.002)	0.014	(0.008)*	-0.011	(0.009)
City planning area (Urbanizaton control area)	0.002	(0.007)	0.000	(0.007)	0.109	(0.020)***	-0.012	(0.032)
City planning area (not designated)	-0.001	(0.012)	0.000	(0.012)	0.006	(0.017)	0.039	(0.029)
Agricultural promotion area	0.017	(0.009)*	-0.000	(0.009)	0.004	(0.013)	0.003	(0.025)
Agricultural promotion area (farmland)	-0.016	(0.008)**	-0.000	(0.008)	-0.006	(0.016)	0.007	(0.026)
Ratio of part-time farmers	0.009	(0.007)	0.000	(0.007)	0.020	(0.005)***	0.027	(0.012)**
Ratio of elderly farmers	-0.011	(0.009)	0.000	(0.009)	-0.018	(0.008)**	-0.011	(0.011)
Nuber of farm households	0.967	(1.121)	0.000	(1.121)	3.601	(0.717)***	1.050	(1.209)

Notes: *, **, ***, indicate statistical significant at 10%;, 5%; and 1%. Robust standard error reported in parenthesis. Dependent variables pre-treatment values in 1990. Samples are restricted to those that suffice common support. Four control communities are matched for nearest neighbor matching. Standard error for nearest neighbor matching is the variance estimator suggested by Abadie and Imbens (2002). Standard errors for kernel and local linear matching are obtained from bootstrapping with 50 repetitions.

Table 8. Heterogenous effects by community conditions

	Ratio of abandoned farmland	Ratio of area planted	Ratio of area rent-in	Ratio of area rent-out	Ratio of area under agricultural service: All work	Ratio of area under agricultural service: Plowing and puddling	Ratio of area under agricultural service: Rice planting	Ratio of area under agricultural service: Mowing and threshing	Ratio of large farmers
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. ATT by gradient									
Readjustment dummy	-0.007	-0.001	0.022	0.012	0.026	0.041	0.034	0.046	-0.011
	(0.010)	(0.011)	(0.012)*	(0.007)*	(0.023)	(0.014)***	(0.010)***	(0.023)**	(0.012)
Readjustment dummy * gradient (gentle)	0.007	-0.001	0.001	-0.010	-0.012	-0.032	-0.027	-0.044	0.033
	(0.016)	(0.016)	(0.019)	(0.011)	(0.025)	(0.018)*	(0.016)*	(0.025)*	(0.018)*
Readjustment dummy * gradient (steep)	-0.016	-0.002	-0.026	-0.008	-0.030	-0.018	-0.042	-0.039	0.022
	(0.018)	(0.017)	(0.018)	(0.010)	(0.024)	(0.023)	(0.013)***	(0.025)	(0.015)
Time-variant controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1056	1055	1055	1055	1055	1055	1055	1055	1056
Adjusted R^2	0.01	0.02	0.02	0.02	0.00	0.01	0.01	0.01	0.02
B. ATT by agricultural area									
Readjustment dummy	-0.013	-0.013	-0.016	0.004	0.046	0.064	0.043	0.036	-0.002
	(0.013)	(0.013)	(0.014)	(0.010)	(0.035)	(0.024)***	(0.019)**	(0.021)*	(0.015)
Readjustment dummy * agricultural area (urban)	0.005	0.043	0.022	-0.008	-0.062	-0.094	-0.080	-0.085	-0.012
	(0.019)	(0.020)**	(0.038)	(0.017)	(0.037)*	(0.030)***	(0.036)**	(0.038)**	(0.028)
Readjustment dummy * agricultural area (intermediate)	-0.000	0.009	0.012	0.005	-0.043	-0.050	-0.041	-0.039	0.007
	(0.016)	(0.016)	(0.018)	(0.011)	(0.036)	(0.027)*	(0.020)**	(0.023)*	(0.016)
Readjustment dummy * agricultural area (mountainous)	0.006	-0.031	0.080	0.001	-0.044	-0.073	-0.057	-0.013	0.028
	(0.028)	(0.025)	(0.025)***	(0.014)	(0.035)	(0.029)**	(0.021)***	(0.031)	(0.017)
Time-variant controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1064	1063	1063	1063	1063	1063	1063	1063	1064
Adjusted R^2	0.01	0.03	0.03	0.03	0.01	0.03	0.03	0.02	0.02

Notes: *, **, ***, indicate statistical significant at 10%;, 5%; and 1%. Robust standard error reported in parenthesis. Time-variant community characteristics controlled are ratio of part-time farmers, ratio of elderly farmers, and number of farm households. Omitted category is gradient (flat) for Panel A and agricultural area (flat) for Panel B.

a) Before. Plots were in irregular shape and sizes were in average 0.05-0.07ha.

b) After. Plots are reshaped and enlarged to mean plot size of 0.5ha.

Figure 1. Example of farmland consolidation project in Niigata, Japan

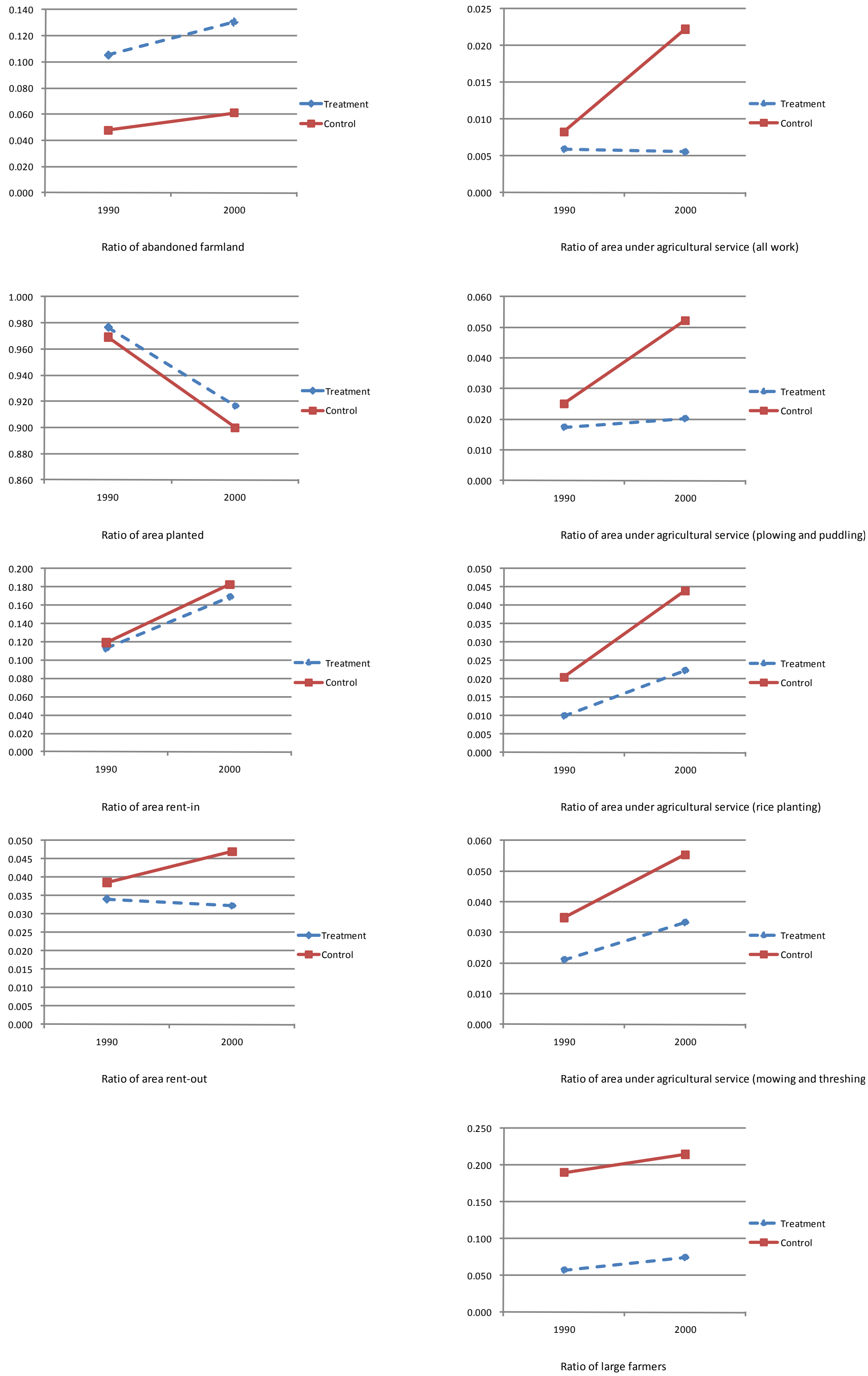

Figure 2. Outcome variables for treatment and control group, before and after treatment