IDEC DP^2 Series Vol. 10 No. 2

Land consolidation and farm production: A difference-in-differences approach with plot exchange in two provinces of Vietnam

Duc TRAN
Global Career Design Center
Hiroshima University

VU Ha Thu
Graduate School of Humanities and Social Sciences
Hiroshima University

Daisaku GOTO
Graduate School of Humanities and Social Sciences
Hiroshima University

Department of Development Policy
Division of Development Science
Graduate School for International Development and Cooperation (IDEC)
Hiroshima University
1-5-1 Kagamiyama, Higashi-hiroshima 7398529 Japan

Land consolidation and farm production: A difference-in-differences approach with plot exchange in two provinces of Vietnam

Duc TRAN [*†‡] VU Ha Thu [*§] Daisaku GOTO [*¶‖]

Abstract

This study evaluates the impacts of land consolidation on household farm production with panel data on 618 rural households in 2010, 2012, 2014, and 2016 in two provinces of Vietnam: Ha Tay and Nghe An. We apply a difference-in-differences approach to address the endogeneity in household participation in plot exchange – a policy for consolidating fragmented cropland in Vietnam. Our approach differs from those of previous studies that typically use a household's number of plots with little treatment of the endogeneity problem. Our results show that plot exchange reduced the number of annual crop plots operated by a household by nearly 50 percent. This land consolidation subsequently improved farm irrigation and the application of machinery. While the impact on farm productivity was statistically insignificant, land consolidation via plot exchange reduced farm labor supply for crop production. Thus, land consolidation could release labor from farms and stimulate an off-farm rural economy.

Keywords – land consolidation, land fragmentation, plot exchange, household farms, Vietnam, difference-in-differences

[*]Graduate School of Humanities and Social Sciences, Hiroshima University, 1-5-1 Kagamiyama, Higashi-Hiroshima, Hiroshima, 739-8529, Japan
[†]Corresponding author
[‡]ductran.inno@gmail.com
[§]hathu.bsc@gmail.com
[¶]Network for Education and Research on Peace and Sustainability (NERPS), Hiroshima University, Japan
[‖]dgoto@hiroshima-u.ac.jp

1 Introduction

Agricultural land fragmentation – whereby household farmland, typically cropland, is split into spatially separated and small plots (McPherson, 1982) – is widespread in Asian countries such as India, Bangladesh, China, and Vietnam (Manjunatha et al., 2013; Rahman and Rahman, 2008; Tan et al., 2008; Hung et al., 2007). Such fragmentation could reduce the productivity of farm labor by incurring traveling time between distant plots (Bentley, 1987). It also hampers irrigation, machinery use, and other interventions intended to improve agricultural productivity (Otsuka et al., 2013; Wan and Cheng, 2001). Thus, the consolidation of fragmented land into more rational landholdings (i.e., larger and better-shaped farms) has been suggested as a focal policy for governments in Asia to facilitate agricultural growth and alleviate poverty (Yamauchi, 2014)[1].

To provide evidence for the implementation of such policy, a significant body of empirical studies has quantified the socioeconomic impacts of land consolidation and fragmentation on household farm production in Asian countries. Since land consolidation and fragmentation are typically defined based on households' numbers of plots, previous studies have frequently directly used this variable in their analyses. Many studies have reported a negative association between the number of plots and farm output, suggesting that land consolidation might raise farm productivity. For instance, Rahman and Rahman (2008) and Manjunatha et al. (2013), employing a stochastic production frontier framework in Bangladesh and India, respectively, found that the number of farm plots was negatively associated with farm production and technical efficiency[2]. Using the same method, Kompas et al. (2012) found that larger farms and larger average plot sizes (i.e., farm size divided by the number of plots) had a positive relationship with production efficiency in Vietnam. Wan and Cheng (2001) also found a negative association between the number of plots and farm productivity in China.

In addition to farm productivity, several studies have analyzed farm households' labor allocation to shed light on the structural changes in rural economies induced by land consolidation. The findings are contradictory. Jia and Petrick (2014) contended that land consolidation had theoretically undetermined impacts on both farm and off-farm labor supply based on a household farm model. With panel data in China, the authors then empirically examined the association of the household number of plots with labor supply and predicted that land consolidation could make farm activities more attractive and subsequently reduce off-farm labor supply. By contrast, Nguyen and Warr (2020) argued that under specific conditions on the production function, land consolidation might reduce farm labor and increase off-farm labor

[1] Land consolidation here refers to the readjustment and rearrangement of fragmented land plots and their ownership (Pasakarnis and Maliene, 2010; Di Falco et al., 2010). Several recent studies have expanded the definition of land consolidation to incorporate concepts related to ecology and culture (e.g., Demetriou et al., 2012 and Zhou et al., 2020), which are beyond the scope of this study.

[2] To indicate the level of land fragmentation and consolidation, Rahman and Rahman (2008) directly used plot numbers in their functions, while Manjunatha et al. (2013) used a dummy variable that equaled 1 if a household owned more than one farm plot and 0 otherwise.

supply. They tested that hypothesis with panel data on rice farmers in Vietnam and found that their instrumented number of plots was positively associated with farm labor supply and negatively associated with off-farm income.

Using the household number of plots to study the impacts of land consolidation, however, might make the findings prone to bias. The number of plots operated, or owned, by a household could be strongly affected by household characteristics, such as age, education level, and wealth. Other characteristics that are rarely observed in survey data such as agricultural skills, knowledge, and political or religious connections within local areas might also determine how many plots a household has. Previous studies often rely on the assumption that with undeveloped land markets, the household number of plots could be independent of the above factors. However, even when the land markets are imperfect, households' plot numbers could have changed due to renting and borrowing (Nguyen and Warr, 2020; Zhang et al., 2020). Therefore, rather than being randomly determined, it is highly plausible that the household number of plots is endogenous. Consequently, when the plot numbers are used as an exogenous variable to investigate the impacts of land consolidation, the findings are likely to be biased.

In this study, instead of using the household number of plots, we exploit household participation in plot exchange, a compelling policy for consolidating cropland in Vietnam, to evaluate the impacts of land consolidation on farm production. The Vietnamese government introduced this policy in 1998. However, its implementation has varied drastically across areas, and importantly, its impacts on farm household production have scarcely been investigated. Our target study sites are two provinces, namely, Ha Tay and Nghe An, which exhibited a high level of land fragmentation and experienced significant progress in land consolidation through plot exchange in the 2010s. Using panel data on 618 rural households in the two provinces obtained from the Vietnam Access to Resource Household Survey (VARHS) in 2010, 2012, 2014, and 2016, we adopt a difference-in-differences (DD) approach to carefully address the endogeneity in household participation in plot exchange.

As our method enables an explicit treatment of the endogeneity problem, which is uncommon in studies using the number of plots, we reexamine the impacts of land consolidation. After confirming that plot exchange reduces the number of plots operated by a household—the direct target of the policy—we estimate the impacts of land consolidation via plot exchange on labor allocation and farm productivity. We also evaluate whether land consolidation can improve irrigation and machinery use. Using different approaches, we check whether our findings are consistent or inconsistent with those of previous studies and thus represent an original contribution to the literature on agricultural land consolidation.

The remainder of this paper is organized as follows. Section 2 describes the background of agricultural land fragmentation and plot exchange as a policy for land consolidation in Vietnam. Section 3 presents the VARHS panel

data, the two study sites, and the outcome variables for the impact evaluation. A detailed explanation of our DD approach and the econometric model used for estimating the impacts is given in Section 4. Section 5 presents the results in terms of impact estimates, sensitivity analysis, and assumption checking. Section 6 discusses our findings in comparison with those of previous studies; Section 7 concludes the paper and offers policy implications.

2 Background

2.1 Land fragmentation in Vietnam

Smallholder crop production on fragmented land is a predominant feature of Vietnamese agriculture. Crop production is the foremost common agricultural activity in Vietnam, and the country is the world-leading exporter of various crop products, such as rice, cassava, coffee, and pepper (World Bank, 2016). However, 89% of all farmers in Vietnam are smallholders whose farms are smaller than 2 hectares (FAO, 2018). The arable land per farmer in Vietnam is only 0.34 hectares, which is approximately half that in other Southeast Asian countries such as Cambodia, Myanmar, or the Philippines (World Bank, 2016). Such small landholdings in Vietnam are further separated into many very small plots; Tarp (2017) indicated that a household had 4.1 on average plots in operation in 2014.

Land fragmentation is the most severe in the North, particularly in the Red River Delta, while it is less pronounced in southern areas such as the Central Highlands and the Mekong River Delta. Approximately 97 percent of agricultural landholdings in the Red River Delta were smaller than 0.5 hectares and only 0.1 percent were larger than 2 hectares in 2011. In contrast, the percentages of holdings larger than 2 hectares in the Central Highlands and Mekong Delta were 23 and 10, respectively (World Bank, 2016). A farming household in the North operated on average 5.5 plots in 2014, which was also higher than the approximately 3 plots per household in the Central Highlands and Mekong Delta (see Tarp, 2017 for changes in the plot number per household in major regions in Vietnam in the period 2006-2014).

The fragmentation of agricultural land in Vietnam is rooted in the economic reforms of the late 1980s and early 1990s (a.k.a *doi moi*). Vietnam embarked on economic reforms that acknowledged private capital and market principles in 1986. In agriculture, economic reforms triggered the decollectivization of land use. Under the Land Laws of 1988 and 1993, land plots for crop production in state agricultural cooperatives were allocated to households with tenure (from 20 to 50 years) and basic use rights, including transfer, exchange, inheritance, and mortgage (Hung et al., 2007).

This land allocation was based on an egalitarian principle to minimize conflicts between households. Specifically, households were assigned balanced sets of crop plots in terms of soil quality, distance to home, and distance to agricultural infrastructure (Markussen et al., 2016). Note that the egalitarian allocation of land from agricultural

cooperatives to households mainly took place in the North. This equity-oriented redistribution might have assured fairness among households; however, its direct and long-lasting consequence is the severe fragmentation of agricultural land in the northern provinces (Ravallion and Van De Walle, 2008). However, in the South, most state agricultural cooperatives could not operate due to strong rejection by farmers. Agricultural land allocation to households was largely based on their holdings before 1975 (Pingali and Xuan, 1992), and thus land fragmentation is less intense there.

2.2 Land consolidation via plot exchange

Agricultural policymakers in Vietnam soon expressed concerns about the difficulties for crop production caused by land fragmentation in the late 1990s (Ministry of Agriculture and Rural Development, 2002; Research Institute of Agricultural Planning, 2004). Land consolidation rose as an urgent agenda, and plot exchange between households was a major policy of the Vietnamese government.

The policy of land consolidation via plot exchange started in 1998, primarily in the North (Hung et al., 2007). With the establishment of a local steering committee, this policy encouraged households to exchange land-use rights and to merge their crop plots after relocation. The purposes of plot exchange were to rationalize the location of crop plots. Ultimately, the policy is expected to reduce the number of crop plots registered under a single household and to facilitate the construction of irrigation infrastructure.

The 2003 Land Law prescribed an administrative procedure for plot exchange (in Term 147 of Decree 181/2004/ND-CP). Accordingly, based on voluntary agreements between households, communal authorities construct plans for the exchange of crop plots and post-exchange land consolidation within their communes. Upon the official approval of district-level governors, plot exchange is executed, and certificates of land-use rights with newly registered locations and plot sizes are given to households. However, there were no common detailed rules regarding how to compensate for differences in the shape, size, and soil quality of the exchanged plots. Instead, households and communal authorities flexibly negotiated plot exchange plans based on the conditions of land fragmentation in the communes.

This context-based execution means that the progress of plot exchange differed dramatically across areas. In the early 2000s, land consolidation through plot exchange reduced plot number in some provinces by up to 50 percent, while limited implementation due to a lack of support from farmers was reported in others (Hung et al., 2007). Conflicts of interest and high transaction costs have been cited as major reasons for the stagnating progress (World Bank, 2016)[3].

[3]First, conflicts of interest are likely since the policy involves exchanging land plots of different soil quality, access to infrastructure, and moral value. In addition, local households could have been suspicious about the implementation of plot exchange since it was administered by a small group of communal authorities. As such, it is not uncommon to find domestic media coverage of prolonged negotiations and even disputes between local households and authorities. Second, high transaction costs in plot exchange may reflect the costs of drawing the communal exchange plan, negotiations, on-sight inspections, and administrative work related to land registration.

Although plot exchange has been a major strategy for land consolidation in Vietnam for decades, very few studies have examined the impacts of this policy on agricultural production and deeper socioeconomic outcomes for farm households. To the best of our knowledge, there are no international publications on this topic. Domestic publications (for example, see Huynh and Nguyen, 2013 and Tran et al., 2017), drawing on case studies in several communes, often only report results based on pre-post comparisons of plot numbers, plot size, and aggregate local agricultural production. Thus, our study addresses this knowledge gap by exploiting available panel data from a household survey to conduct a more rigorous impact evaluation of plot exchange on farm households in Vietnam.

3 Data and target study sites

3.1 VARHS balanced panel data

The data used in this study come from the VARHS conducted in 2010, 2012, 2014, and 2016. The VARHS offers a panel data set that is representative of rural areas in 12 provinces. As shown in Figure 1, the 12 provinces covered by the VARHS spread across all major geographical regions in Vietnam. In addition to the panel structure and national coverage, another strong merit of the VARHS is its detailed questionnaire on household land use. This data set provides rich information on the size, contemporary use, investment, and land transactions of each household land plot. This plot-level data, when combined with other VARHS data on household farm production, labor, and income, enables in-depth evaluations of land policies in rural areas of Vietnam.

Importantly, the VARHS questionnaire enables us to identify household participation in the plot exchange. The questionnaire has a section about household land plots that are either sold, expelled, given away, or permanently exchanged since the last survey wave 2 years prior to the current survey wave. If a household had one of these transactions, more detailed information about the relevant plots (e.g., the plot code in the last survey wave, year of transaction, area of the transaction and type of transaction) is recorded. Therefore, we rely on households' self-reports on whether they had any land plots that were permanently exchanged in each survey wave to determine their participation in plot exchange[4]. We then can exploit variations in time and household participation in plot exchange to study the impacts of this policy using VARHS panel data.

We construct a balanced panel sample based on four survey waves in 2010, 2012, 2014, and 2016 as a first step to

[4]Note that the households that had exchanged plots can be considered households participating in the local plot exchange program, rather than households engaging in spontaneous plot exchange with others. Due to the procedure described in the background section, plot exchange is rarely implemented by scattered agreement among individual households. Instead, local programs for plot exchange simultaneously involving many households are the typical practice.

study plot exchange using VARHS data. We merge the data sets and retain the households that were interviewed in all four survey waves[5]. The balanced VARHS sample consists of 1,992 households in 12 provinces.

3.2 Target study sites

To evaluate the impacts of land consolidation via plot exchange using VARHS data, we restrict our analysis to two target provinces, namely, Ha Tay and Nghe An. The areas numbered one and six in Figure 1 show the locations of the two provinces. We cautiously justify the selection of these two provinces for our impact evaluation.

First, land fragmentation was particularly severe in Ha Tay and Nghe An. Before reunification in 1975, both provinces were in North Vietnam and under the communist government. Local agricultural land, especially cropland, was heavily fragmented by egalitarian land reallocation in the 1990s economic reforms. Using our balanced sample of VARHS in 2010, we compare the number and size of and crop plots in the two provinces with the sample average and with the average of provinces in the Central Highlands or the Mekong Delta River. As seen in Table A.1 in the Appendix, the two provinces have a much smaller (total and average) crop plot size and a larger number of crop plots, particularly compared to provinces in the Central Highlands or the Mekong Delta River.

Second, due to intense land fragmentation, there were remarkable efforts at plot exchange in the two provinces in the 2010s. In Ha Tay, following the mass expiration of land-use certificates for land plots for annual crop production[6], the province started to allocate an additional budget to intensify plot exchange through Decision 04/2012/NQ-HDND in 2012. Similarly, the provincial governors of Nghe An directed local communes to construct new plans for plot exchange through Decision 08-CT/TU in 2012. In both provinces, the policy objective was to reduce the number of crop plots registered under one household to only 1-2 plots.

Our balanced VARHS sample also reflects the corresponding progress in plot exchange in the two provinces. Figure A.1 shows the number of households in our sample who engaged in plot exchanges in the period 2008-2016. It is easily noticeable that there was a dramatic increase from 2012-2014. The number of households having plot exchange rose sharply from only 9 in 2008-2010 or 8 in 2010-2012 to 185 in 2012-2014, before declining to 51 in 2014-2016. Moreover, this surge in plot exchange only clustered in Ha Tay and Nghe An. A total of 176 of the 185 households with plot exchanges in 2012-2014 were located in these two provinces. This ratio was 44 out of 51 in 2014-2016.

Third, with plot exchange in our data clustering heavily in Ha Tay and Nghe An, the selection of households in

[5]We utilized STATA 14 for data cleaning and analysis. In the data cleaning stage, we corrected apparent mistakes related to households' geographical location and land use. All changes can be tracked in our STATA do-files that are available upon request.

[6]Land plots for annual crop production were allocated to households in the early 1990s with a tenure of 20 years, which led to a mass expiration of land-use certificates for this land class in the early 2010s. The Land Law of 2013 increased the tenure of land for annual crop production to 50 years; Vu and Goto (2020) investigated the impacts of this policy on agricultural investment.

these two provinces improves the credibility of our impact evaluation. Impact evaluation methods using panel data can address biases caused by unobserved confounders – factors affecting both treatment (i.e., plot exchange in this study) and outcome variables – that are time-invariant. However, unobserved time-variant confounders are assumed to be independent of the treatment. There are several potential unobserved time-variant confounders in our study, for instance, weather shocks, regional socioeconomic development, and local agricultural policies other than plot exchange. Since our selection restricts the analysis to households with and without plot exchange within Ha Tay and Nghe An, they should have fewer systematic differences in unobserved time-variant confounders. As such, we can mitigate biases in evaluating the impacts of plot exchange using our panel data.

Due to the three critical factors listed above, we only use a balanced panel sample of households in Nghe An and Ha Tay for our impact evaluation. In addition, to focus on the impacts of the surge in plot exchange from 2012-2014, we further exclude a minority of 10 households that had plot exchange in 2008-2012. Ultimately, we obtain a balanced sample of 618 households in the four survey waves. Among them, the treatment group contains 205 households having plot exchange either in 2012-2014 or 2014-2016. The control group consists of 413 households not having plot exchange in 2008-2016[7].

3.3 Outcome variables

We evaluate the impacts of plot exchange on four groups of outcome variables. The detailed definitions of all outcome variables and their descriptive statistics using our balanced sample in the two provinces are shown in Tables A.2 and A.3, respectively, in the Appendix.

The first group includes the number and size of plots operated by a household. Based on the typology of land in the Land Law and the VARHS questionnaire, we distinguish impacts on four classes of land plots: annual crop plots, perennial crop plots, other agricultural plots (land plots for forestry, aquaculture, and pasture), and non-agricultural plots (residential land and houses with gardens). Since the ultimate target of plot exchange is to reduce the number of household plots, particularly crop plots, the impacts on this group of variables show the most direct outcome of the policy. The results enable us to confirm whether our utilization of households' self-reported plot exchange can identify land consolidation at the household level and further evaluate its impacts.

The second group relates to irrigation and machinery use. Rational landholdings resulting from land consolidation are expected to facilitate the construction of agricultural infrastructure and the application of machinery in farming.

[7]The control group in our sample should not be considered households that had never engaged in plot exchanged by 2016. Some of the households might have exchanged land plots before 2008, a period not covered by our available data. However, assuming that the impacts of plot exchange were unchanged over time, it remains valid to use this control group, which had no additional plot exchange in 2008-2016, to evaluate the impact evaluation of plot exchange in this period.

Based on available data in the VARHS, we test this hypothesis by evaluating the impacts of plot exchange on access to public irrigation, new household investment in irrigation, and household expenditures on rental machines for crop production.

The third group refers to labor allocation. The VARHS offers detailed data on the number of days that household members spend on various agricultural activities and wage employment. We aggregate the labor days for each activity at the household level and estimate the impacts of plot exchange on those variables. We also examine the impacts on hired labor for crop production measured cash expenditures for outside laborers.

The fourth and final group is farm productivity – a typical outcome in studies on land consolidation. Since cropland is the focus of plot exchange, we examine the impacts on land productivity with respect to all crop production and annual crop production – both measured in monetary value per hectare. In addition, we estimate the impacts on rice productivity – the most major crop in Vietnam and the two target provinces.

4 Econometric model

With our balanced panel sample and a strong variation in the number of households participating in plot exchange, we apply the DD approach to estimate the impacts of plot exchange on the outcome variables of interest. This approach first computes the average differences, or trends, in an outcome variable before and after the treatment (i.e., plot exchange) for both the treatment and control groups. It then takes the second difference in these trends between the treatment and control groups. Under the assumption that the trends of the two groups would have been the same without the treatment (i.e., the parallel trends assumption), the second difference gives us an unbiased estimate of the average treatment effect on the treated (ATET) on the outcome variable.

We adapt the DD approach to our data to fully exploit all variations in time and treatment timings. A typical DD involves only two time periods and one treatment timing. Our data have four periods, and the treated households could have exchanged plots in either 2012-2014 or 2014-2016. As such, we follow the recommendation of Angrist and Pischke (2009) and apply a "two-way fixed effects" regression model that fits multiple time periods and treatment timings. Equation 1 specifies the model that we use to obtain ATE estimates.

$$Y_{it} = \alpha_t + c_i + \delta Exchange_{it} + \theta X_{it} + u_{it} \tag{1}$$

Y_{it} is an outcome variable of household i in time period t. α_t represents year fixed effects and is a set of dummy variables for each year in the data, excluding 2010 as the baseline. c_i captures individual household fixed effects.

$Exchange_{it}$ is a dummy variable indicating whether household i had plot engaged in exchange by year t. $Exchange_{it}$ can be considered as the interaction term between treatment and time variables in the conventional DD regression. However, instead of being switched on (i.e., changing from 0 to 1) for all observations after a unique treatment timing, it is only switched on for a treated household if that household had plot engaged in exchange by the year t. This variable thus allows households to have the treatment at different timings. δ is our coefficient of interest presenting the estimate of the ATET. X_{it} includes demographics of the household head (age, gender, and education level) and household size. u_{it} is the error term.

We run the above regression model and obtain the estimates of δ for all the outcome variables. We also estimate the standard errors clustered at the commune level for the statistical inference of the estimates. One critical reason is that plot exchange was implemented among households living in the same commune. Therefore, clustering the standard errors at the commune level accounts for the potential correlations in treatment status and outcome variables among households within the same communes in our statistical inference.

5 Results

5.1 ATET estimates

Table 1 presents the ATET estimates on the number and size of plots operated by a household. Plot exchange dramatically affected the number of plots for crop production. However, among the two types of crop plots, plot exchange significantly reduced the number of annual crop plots by approximately three plots, and the impact was fairly similar between the two provinces. This drop was substantial and equivalent to nearly half of the number of annual crop plots that a treated household had on average in 2010 (6.31 plots as indicated in Table A.3). However, the plot numbers for perennial cropland, similar to other land classes, remained largely unaffected.

Regarding land size, plot exchange did not lead to any significant changes for all land classes when all ATET estimates were close to zero. With the decreasing plot number and unchanged size, it is straightforward to infer that plot exchange increased the average size of an annual crop plot. Using the same regression model, we estimate this positive effect to be approximately 0.04 hectares. Since the average size of one annual crop plot for the treated group was also approximately 0.04 hectares in 2010, plot exchange doubled the average size of an annual crop plot.

The results of the first group of outcome variables confirm the validity of our identification strategy. The strong negative ATET on the number of annual crop plots and the null impacts on plot size support the notion that by using households' self-report participation in plot exchange, we can identify consolidation of cropland at the household level.

As such, we can interpret subsequent results for other groups of outcome variables as the impacts of land consolidation through plot exchange.

Table 2 reports the impacts on irrigation and machinery use. The consolidation of annual cropland via plot exchange significantly increased the likelihood that households could rely on public irrigation for their crop production by 9 percentage points. This impact was most pronounced in Nghe An, where the likelihood increased significantly by 18 percentage points. Similarly, households that had plots exchanged in Nghe An were slightly more likely to make a new investment in irrigation, although the corresponding ATET estimate was only marginally significant at 10% level.

Plot exchange also increased households' spending on rental machines by 0.18 million VND on average. The ATET estimate was statistically significant in Ha Tay but not in Nghe An, despite presenting quite similar magnitudes (0.17 and 0.14 million VND, respectively). This is plausibly due to substantial statistical noise resulting from the smaller sample size in the latter.

Table 3 shows the ATET estimates on labor allocation. We found significant impacts on the number of days household members spent on crop production. On average, plot exchange reduced labor for crop production by 21.14 days – equivalent to 17.11% compared to the 2010 baseline level. The impact mostly came from released labor on rice (12.44 days) and other crops (7.8 days). However, there were relative differences between the two provinces. The impact was less strong (17.84 days) in Ha Tay and mainly came from a reduction in labor spent on other crops. However, in Nghe An, the impact was stronger (33.27 days), and a significant reduction in labor for rice production (25.24 days) accounted for most of the effect. The impact on hired labor for crop production was insignificant in the full sample and in each province. Similarly, although the ATET estimates on labor for wage employment were positive, we could not find any statistically significant estimates in either province[8].

Finally, we present the impacts of plot exchange on crop productivity in Table 4. In general, we could not find any significant impacts on all outcome variables. The ATET estimates on the productivity of all crops and annual crops differed between the two provinces; however, they were all not statistically insignificant. Similarly, the impacts on rice productivity, measured in kilograms per hectare, were not significant in the pooled sample analysis and the separate analysis in each province.

5.2 Sensitivity analysis and placebo test

We also vary our analysis and examine the sensitivity of the ATET estimates. Since the main target of plot exchange was crop plots, we exclude 44 households that did not have any crop plots in the four data waves before running the

[8] We also tested the impacts on other agricultural activities that are less relevant to plot exchange, including forestry, livestock and fishery. All ATET estimates were insignificant.

regression model as in Equation 1. The results from this analysis are shown in Tables A.4 and A.5 in the Appendix. The ATET estimates are largely consistent with those presented in the full sample analysis. Only a few ATET estimates, such as expenditures for fertilizer in Nghe An and labor days spent on rice production, show slight differences in the level of statistical significance. However, our findings are generally unaffected.

Importantly, we probe the important parallel trends assumption for the DD method to provide evidence for the credibility of our ATET estimates. Since our panel data cover two time periods before the treatment, 2010 and 2012, we conduct placebo tests to check whether, regarding one outcome variable, the trends of the treatment and control groups are parallel before the treatment took place in 2012-2014. If this is the case, we can argue that the trends of the two groups would have been parallel without the treatment. This placebo test restricts the sample to the panels in 2010 and 2012, and we can use a typical DD regression model as described in Equation 2.

$$Y_{it} = \alpha + \beta Treat_i + \gamma Year_{2012} + \delta_{placebo} Treat_i Year_{2012} + \theta X_i + u_i \quad (2)$$

$Year_{2012}$ is a dummy variable for the year 2012. $Treat_i$ is a dummy variable showing whether household i is in the treatment group – households that engaged in plot exchange later in 2012-2016. $\delta_{placebo}$ indicates whether there were any differences in the trends of an outcome variable between the treatment and control groups before the treatment took place. Therefore, if $\delta_{Placebo}$ is small and statistically insignificant, we can justify the plausibility of the parallel trends assumption.

We present the results of our placebo test in Table 5. The estimates of $\delta_{placebo}$ are insignificant for almost all outcome variables, suggesting high plausibility of the parallel trends assumption. One of the few exceptions is the expenditure for rental machines, which increased significantly faster for the treatment group in 2010-2012.

6 Discussion

We interpret our ATET estimates and compare our findings with those from studies using the number of plots to evaluate the impacts of land consolidation. First, our results regarding the strong impacts on the number of annual crop plots and the small impacts on other land classes reflect the target of land consolidation in the two study sites. The egalitarian land allocation during the economic reform in the early 1990s mainly involved land plots for annual crop production (e.g., rice, maize, and vegetables). As such, this land class was typically the main source of land fragmentation. Our data in 2010 show that on average, a household in Ha Tay or Nghe An had 5.89 plots, of which 4.72 plots were registered for annual crop production. Due to this high level of fragmentation, reducing the number of annual crop plots became

the main target of plot exchange, which is reflected in our ATET estimates. However, since the fragmentation of other agricultural land classes was less severe, plot exchange is expected to have little impact on those land classes.

The positive impacts on irrigation-related outcome variables demonstrate a largely unconfirmed benefit of land consolidation. In addition to reducing the number of plots, another common purpose of land consolidation is to rationalize the arrangement of land plots, which in turn facilitates the construction of agricultural infrastructure. However, we could not find any empirical studies that reported this impact. Our results provide original evidence that treated households were more likely to access reliable public irrigation and that they were also more likely to make a new investment in irrigation[9].

The impact on machinery use is generally consistent with the findings of previous studies. In China, Lai et al. (2015) indicated that machinery use increased by 10% when land plots were consolidated from 2.28 plots to one plot. Nguyen and Warr (2020) showed that a 10% decrease in plot number increased the expenditure on rental machines for rice production by 1.79% in Vietnam in 2008. We found a similar but more substantial impact in our case study. Land consolidation through plot exchange led to an approximately 50% reduction in the number of annual crop plots and a 64.3% increase in the expenditure for rental machines (compared to the 2010 baseline of the treated households). However, this result should be interpreted with caution since we cannot find evidence to support the assumption of parallel trends for this outcome variable.

Regarding labor allocation, our findings are consistent with the studies of Wan and Cheng (2001) and Nguyen and Warr (2020), where land consolidation significantly reduced farm labor. Our positive but statistically insignificant ATET on off-farm labor supply is also similar to the result of Nguyen and Warr (2020), although they found an additional positive impact on off-farm income. Our findings, however, differ from the argument of Jia and Petrick (2014), as their empirical results suggested that land consolidation might attract labor to farm production and reduce off-farm labor supply.

We could not find a positive impact of land consolidation on productivity, which is commonly reported in studies using the household number of plots in their analysis (e.g., Wan and Cheng, 2001, Rahman and Rahman, 2008, Manjunatha et al., 2013 and Kompas et al., 2012). Although the statistical insignificance of our ATET estimates prevents us from drawing a concrete conclusion, we again argue that previous studies using the number of plots without adequate treatment for endogeneity might have overestimated the impacts of land consolidation on agricultural productivity. There could be a range of unobserved confounders – such as household knowledge of and motivation for agricultural production or political connections with local governments – that make such overestimation probable. In our approach,

[9]The stronger impacts in Nghe An plausibly resulted from the province's less developed irrigation systems compared to Ha Tay, which is located in the Red River Delta, a center for crop production in Vietnam.

by exploiting household participation decisions in land consolidation through plot exchange, we carefully treat this endogenous decision and check the assumptions for our identification of the causal effects. Thus, our estimates are more resistant to biases than those in previous studies using the number of plots.

7 Conclusion

This study uses panel data on 618 rural households in 2010, 2012, 2014, and 2016 in two provinces in Vietnam – Ha Tay and Nghe An – to evaluate the impacts of land consolidation on farm production. We apply a DD approach to exploit household participation in plot exchange, a policy for the consolidation of cropland in Vietnam. The strong advantage of the DD method is that we can mitigate the endogeneity problem related to household participation decisions and thus obtain credible estimates of the causal effects. Our approach differs from those of previous studies that typically use the household number of plots with little treatment of the endogeneity problem to investigate the impacts of land consolidation and fragmentation. We estimate the impacts of the consolidation policy on the number of plots operated by a household, irrigation and machinery use, allocation of household labor to on-farm and off-farm activities, and farm productivity.

Our estimates present findings that are both consistent and inconsistent with previous literature on land consolidation. The policy of plot exchange reduced the plot numbers by approximately 50% and doubled the average size of a plot for annual cropland. This consolidation of cropland enabled households to access reliable public irrigation and make new investment in irrigation. Consistent with previous studies, we found that land consolidation increased application of machinery in farming. Regarding labor allocation, land consolidation via plot exchange significantly reduced labor allocated to crop production, while the impact on off-farm labor supply was statistically insignificant. However, when using our DD approach for more accurate causal inference, we could not confirm the positive impacts of land consolidation on farm productivity – a regular finding in studies using the number of plots.

The findings of our case study have two implications for agricultural land consolidation. First, plot exchange could be a viable policy for addressing land fragmentation in agriculture. Although this policy may trigger conflicts of interest and high transaction costs, when it is possible to reach a final agreement on the exchange plan, as in the two study sites of our case study, it can dramatically reduce land fragmentation. Therefore, in addition to policies involving significant institutional changes such as land ownership or land rental markets (Hung et al., 2007), policy-makers in regions that exhibit a high level of land fragmentation could consider plot exchange between households to rationalize local agricultural landholdings. Subsequently, it is possible to construct better irrigation systems and to more intensively

apply machinery. Second, our results regarding the impacts on labor allocation reveal potential changes in the rural economy induced by land consolidation. To this end, we reach a quite similar conclusion to that of Nguyen and Warr (2020) that land consolidation could release labor from farms and, therefore, stimulate an off-farm rural economy.

Finally, we acknowledge the limitations of our study. To guarantee the identification of the causal impacts, we use only a sample of households in Ha Tay and Nghe An. This small sample could constrain the generalization of our findings to other areas in Vietnam. Our results also show that several impacts are different between the two provinces. Therefore, we recommend that one should be cautious when extrapolating the results of our case study to other areas. In addition, the DD method assumes that the trends of the outcome variables would have been the same between the treatment and control if the treatment had not happened. We conducted placebo tests with pretreatment data to support the plausibility of this assumption; however, the assumption itself cannot be tested. As such, together with the first limitation, we expect future studies to exploit as-if natural experiments in landholdings at a larger scale to have more conclusive evidence on the impacts of land consolidation on farm production.

Appendix

Figure A.1

Table A.1

Table A.2

Table A.3

Table A.4

Table A.5

Figures

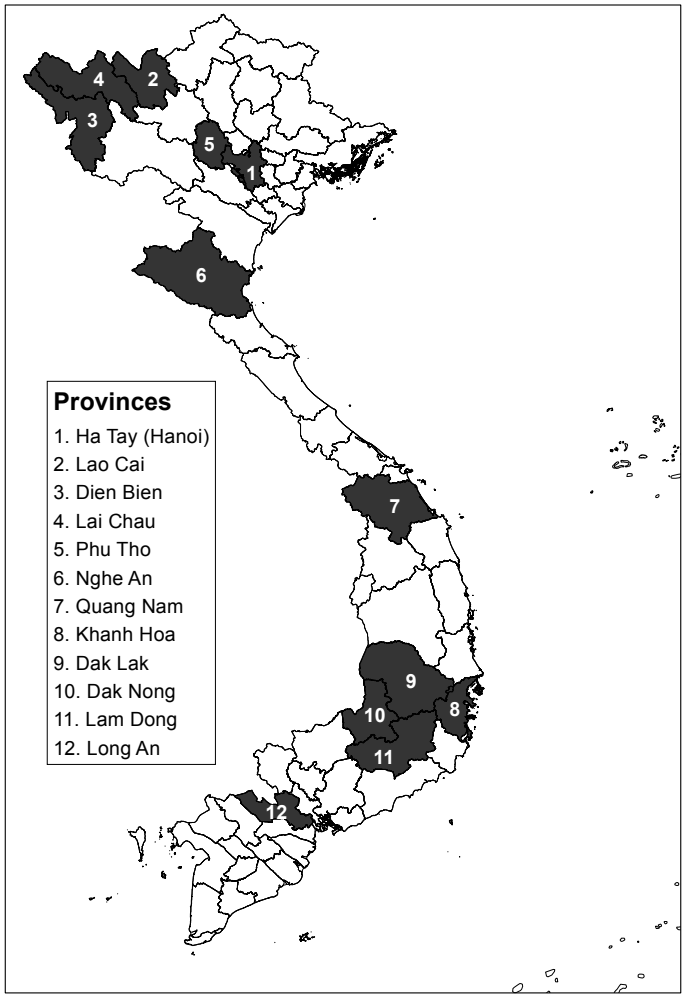

Figure 1: Provinces covered by the VARHS

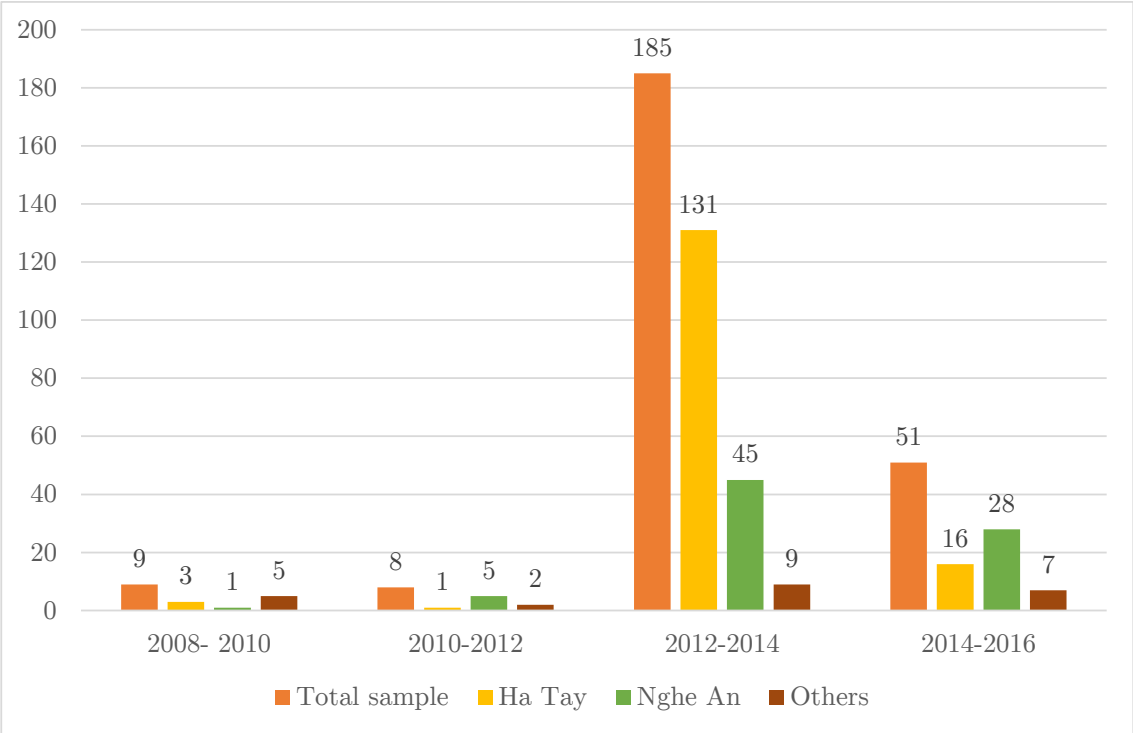

Figure A.1: Number of households engaged in plot exchange from 2008 to 2016

Tables

	Two provinces		Ha Tay		Nghe An	
	Coef.	**S.E.**	**Coef.**	**S.E.**	**Coef.**	**S.E.**
Number of land plots						
Number of annual crop plots	-3.06***	0.20	-3.18***	0.25	-2.83***	0.32
Number of perennial crop plots	-0.01	0.02	-0.01	0.02	-0.01	0.03
Number of other agricultural plots	0.00	0.02	0.01	0.03	-0.04	0.03
Number of non-agricultural plots	-0.01	0.03	-0.03	0.03	0.01	0.04
Size of land plot (ha)						
Size of annual crop plots	0.00	0.01	0.00	0.01	0.00	0.03
Size of perennial crop plots	-0.01	0.01	0.00	0.01	-0.03	0.03
Size of other agricultural plots	0.00	0.01	-0.01	0.01	0.02	0.02
Size of non-agricultural plots	0.00	0.00	0.00	0.00	0.00	0.01
Observations (n)	2,472		1,760		712	

**** 1% significant level, ** 5% significant level, * 10% significant level. Standard errors (S.E.) are clustered at commune level.*

Table 1: ATET on the numbers and sizes of plots

	Two provinces		Ha Tay		Nghe An	
	Coef.	**S.E.**	**Coef.**	**S.E.**	**Coef.**	**S.E.**
Irrigation and machinery use						
Access to public irrigation (1=yes, 0=no)	0.09***	0.03	0.05	0.04	0.18***	0.06
New investment in irrigation (1=yes, 0=no)	0.02*	0.01	0.01	0.01	0.03*	0.02
Rental machines (Mil. VND)	0.18***	0.06	0.17***	0.06	0.14	0.12
Observations (n)	2,472		1,760		712	

10% significant level, ** 5% significant level, * 1% significant level. Standard errors (S.E.) are clustered at commune level. Monetary values are adjusted to the 2010 constant price.*

Table 2: ATET on irrigation and machinery use

	Two provinces		Ha Tay		Nghe An	
	Coef.	**S.E.**	**Coef.**	**S.E.**	**Coef.**	**S.E.**
Labor allocation (days)						
Crop production	-21.14***	5.32	-17.84**	6.82	-33.76***	7.32
Rice	-12.44***	3.97	-7.95	4.85	-25.24***	5.99
Maize	-0.90	1.07	0.58	0.86	-4.28	2.59
Other crops	-7.80**	3.61	-10.47**	4.94	-4.25	3.78
Hired labor (Mil. VND)	-0.16	0.13	-0.20	0.17	-0.05	0.14
Off-farm	15.80	17.56	14.16	24.09	24.16	23.91
Observations	2,472		1,760		712	

10% significant level, ** 5% significant level, * 1% significant level. Standard errors (S.E.) are clustered at commune level. Monetary values are adjusted to the 2010 constant price.*

Table 3: ATET on labor allocation

	Two provinces			Ha Tay			Nghe An		
	n	**Coef.**	**S.E.**	**n**	**Coef.**	**S.E.**	**n**	**Coef.**	**S.E.**
Farm productivity									
All crops (Mil. VND/ha)	2188	-1.10	6.19	1606	2.94	6.23	582	-10.23	9.49
Annual crop (Mil. VND/ha)	2171	1.54	4.72	1595	0.31	6.60	576	1.44	2.70
Rice (ton/ha)	1710	0.27	0.64	1241	0.51	0.62	469	0.24	1.73

10% significant level, ** 5% significant level, * 1% significant level. Standard errors (S.E.) are clustered at commune level. Monetary values are adjusted to the 2010 constant price.*

Table 4: ATET on farm productivity

Outcome variables	Full sample		Only HHs with crop plots	
	Coef.	S.E.	Coef.	S.E.
Number of land plots				
Number of annual crop plots	0.24	0.16	0.27*	0.16
Number of perennial crop plots	0.01	0.02	0.01	0.02
Number of other agricultural plots	-0.04	0.03	-0.04	0.03
Number of non-agricultural plots	-0.05	0.03	-0.05	0.04
Size of land plot (ha)				
Size of annual plots	-0.01	0.01	-0.01	0.02
Size of perennial plots	-0.01	0.01	-0.01	0.01
Size of other agricultural plots	-0.03	0.02	-0.03	0.02
Size of non-agricultural plots	0.00	0.00	0.00	0.00
Irrigation and machinery use				
Access to public irrigation (1 = yes, 0 = no)	0.03	0.05	0.03	0.05
New investment in irrigation (1 = yes, 0 = no)	0.00	0.01	0.00	0.01
Renting machines	0.29***	0.07	0.28***	0.07
Household labors (days)				
Crops	0.28	8.46	-0.55	8.85
Rice	5.85	5.89	6.21	6.28
Maize	-1.44	1.67	-1.51	1.74
Other crops	-4.13	6.71	-5.25	6.87
Hired labor (Mil. VND)	0.01	0.10	0.00	0.10
Off-farm	28.42	28.40	31.69	30.19
Farm productivity[a]				
All crops (Mil. VND/ha)	6.24	10.64	6.24	10.64
Annual crops (Mil. VND/ha)	2.13	5.00	2.13	5.00
Rice (ton/ha)	1.34*	0.71	1.34*	0.71
Observations (n)	1236		1148	

10% significant level, ** 5% significant level, * 1% significant level. Standard errors (S.E.) are clustered at commune level.*
[a]The number of observations for the estimations of all crops, annual crops and rice are 1096, 1090, and 906, respectively.
Monetary values are adjusted to the 2010 constant price.

Table 5: Results of the placebo tests

	Ha Tay	Nghe An	VARHS sample average	Central Highland and Mekong Delta
Number of crop plots	5.06	4.07	3.95	2.64
Total size of cropland (ha)	0.20	0.32	0.60	0.89
Average size (ha/plot)	0.04	0.1	0.23	0.43

Table A.1: Land fragmentation in Ha Tay and Nghe An

Outcome variables	Definition
Number of land plots	
Number of annual crop plots	The number of plots registered for annual crop production operated by a household (plots)
Number of perennial crop plots	The number of plots registered for perennial crop production operated by a household (plots)
Number of other agricultural plots	The number of plots registered for forestry, aquaculture and pasture operated by a household (plots)
Number of non-agricultural plots	The number of plots registered as residential area and house-with-garden operated by a household (plots)
Size of land plot	
Size of annual plots	The total size of plots registered for annual crop production operated by a household (ha)
Size of perennial plots	The total size of plots registered for perennial crop production operated by a household (ha)
Size of other agricultural plots	The total size of plots registered for forestry, aquaculture and pasture operated by a household (ha)
Size of non-agricultural plots	The total size of plots registered as residential area and house-with-garden operated by a household (ha)
Irrigation and machinery use	
Access to public irrigation	A dummy indicating whether a household has access to reliable public or cooperative irrigation (1 = yes, 0 = no)
New investment in irrigation	A dummy indicating whether a household has new investment in irrigation (1 = yes, 0 = no)
Rental machines	Household expenditure for renting outside machines for crop production (Mil. VND)
Household labors (days)	
All crops	The number of days that household members spent on all crop production (days)
Rice	The number of days that household members spent on rice production (days)
Maize	The number of days that household members spent on maize production (days)
Other crops	The number of days that household members spent on the production of other crops (days)
Hired labor	Household expenditure for hiring outside labor for crop production (Mil. VND)
Off-fam	The number of days that household members spent on off-farm employment (days)
Farm productivity	
All crops	Value of all crop produce (self-consumption included) divided by the total size of crop plots (Mil VND/ha)
Annual crop	Value of annual crop produce (self-consumption included) divided by the size of annual crop plots (Mil VND/ha)
Quantity of rice	Amount of rice produce divided by the size of rice farm (ton/ha)

Table A.2: Definitions of the outcome variables

Outcome variables	2010						2016					
	Control (n = 413)		Treated (n=205)		Difference		Control (n = 413)		Treated (n=205)		Difference	
	Mean	S.D.	Mean	S.D.	Mean	S.E.	Mean	S.D.	Mean	S.D.	Mean	S.E.
Number of land plots												
Number of annual crop plots	3.93	3.24	6.31	2.91	2.38 ***	0.27	3.31	2.73	2.76	1.53	-0.56 ***	0.21
Number of perennial crop plots	0.08	0.39	0.03	0.22	-0.05 *	0.03	0.08	0.35	0.03	0.18	-0.04 *	0.03
Number of other agricultural plots	0.07	0.29	0.02	0.18	-0.05 **	0.02	0.09	0.35	0.01	0.12	-0.08 ***	0.02
Number of non-agricultural plots	1.05	0.21	1.04	0.24	0.01	0.02	1.10	0.38	1.08	0.33	0.01	0.03
Size of land plot (ha)												
Size of annual plots	0.19	0.22	0.22	0.14	0.04 **	0.02	0.17	0.25	0.19	0.12	0.02	0.02
Size of perennial plots	0.05	0.35	0.00	0.04	0.05 *	0.02	0.05	0.33	0.00	0.01	0.05 **	0.02
Size of other agricultural plots	0.05	0.34	0.01	0.14	0.04	0.02	0.06	0.39	0.00	0.04	-0.05 *	0.03
Size of non-agricultural plots	0.05	0.09	0.05	0.07	0.00	0.01	0.05	0.08	0.06	0.08	0.00	0.01
Irrigation and machinery use												
Access to public irrigation	0.80	0.40	0.87	0.33	0.07 **	0.03	0.72	0.45	0.96	0.19	0.24 ***	0.03
New investment in irrigation (1 = yes, 0 = no)	0.01	0.10	0.00	0.07	0.00	0.01	0.01	0.12	0.02	0.15	-0.01	0.01
Renting machines (Mil. VND)	0.31	0.55	0.28	0.39	-0.02	0.04	0.49	0.94	0.81	0.81	0.31 ***	0.08

10% significant level, ** 5% significant level, * 1% significant level. Monetary values are adjusted to the 2010 constant price*

(Continued)

Table A.3: Descriptive statistics of the outcome variables in 2010 and 2016

Outcome variables	2010						2016					
	Control (n = 413)		Treated (n=205)		Difference		Control (n = 413)		Treated (n=205)		Difference	
	Mean	S.D.	Mean	S.D.	Mean	S.E.	Mean	S.D.	Mean	S.D.	Mean	S.E.
Household labors (days)												
All crops	85.75	85.10	123.55	74.65	37.80 **	6.99	51.61	64.36	64.27	64.03	12.66 **	5.49
Rice	61.64	65.80	91.57	59.53	29.92 ***	5.45	31.51	43.69	50.12	42.83	18.61 ***	3.71
Maize	5.13	19.12	6.24	13.80	1.12	1.50	2.55	11.05	3.07	11.35	0.51	0.95
Other crops	18.98	38.30	25.74	40.18	6.76 **	3.33	17.55	42.73	11.08	40.16	-6.46 *	3.58
Hired labor (Mil. VND)	0.29	0.63	0.44	0.73	0.16 ***	0.06	0.68	1.72	0.67	0.88	0.02	0.13
Off-farm employment	241.81	264.34	200.73	224.56	-41.08 *	21.52	241.87	251.23	220.91	257.00	-20.95	21.63
Farm productivity												
All crops (Mil. VND/ha)	49.42	61.43	50.76	55.35	1.34	5.23	36.79	47.97	36.10	25.55	0.69	3.65
Annual crop (Mil. VND/ha)	45.73	41.35	44.94	23.65	-0.79	3.17	34.96	45.16	34.42	18.90	0.54	3.35
Rice (ton/ha)	9.69	6.83	8.91	2.13	0.78	0.52	9.89	2.51	10.18	3.58	0.28	0.31

10% significant level, ** 5% significant level, * 1% significant level. Monetary values are adjusted to the 2010 constant price.*

Table A.3: (Continued)

	Two provinces		Ha Tay		Nghe An	
	Coef.	**S.E.**	**Coef.**	**S.E.**	**Coef.**	**S.E.**
Number of land plots						
Number of annual crop plots	-3.01 ***	0.28	-3.15 ***	0.38	-2.76 ***	0.33
Number of perennial crop plots	-0.01	0.02	-0.01	0.03	-0.01	0.04
Number of other agricultural plots	-0.01	0.03	0.01	0.03	-0.05	0.04
Number of non-agricultural plots	-0.01	0.04	-0.03	0.05	0.03	0.04
Size of land plot (ha)						
Size of annual crop plots	0.00	0.01	0.00	0.01	0.00	0.03
Size of perennial crop plots	-0.01	0.01	0.00	0.01	-0.03	0.03
Size of other agricultural plots	0.00	0.01	-0.01	0.01	0.02	0.02
Size of non-agricultural plots	0.00	0.00	0.00	0.00	0.00	0.01
Irrigation and machinery use						
Access to public irrigation (1=yes, 0=no)	0.06 *	0.03	0.04	0.04	0.09 *	0.05
New investment in irrigation (1=yes, 0=no)	0.02 *	0.01	0.01	0.01	0.03 *	0.02
Renting machines (Mil. VND)	0.17 ***	0.06	0.16 **	0.06	0.09	0.13
Labor allocation (days)						
Crop production	-18.61 ***	5.43	-16.15 **	6.79	-29.66 ***	7.95
Rice	-9.70 **	3.98	-6.37	4.75	-20.83 ***	6.51
Maize	-0.95	1.12	0.64	0.87	-4.76	2.89
Other crops	-7.95 **	3.76	-10.42 **	5.02	-4.07	4.14
Hired labor (Mil. VND)	-0.18	0.14	-0.21	0.18	-0.12	0.15
Off-farm	12.53	18.15	12.19	21.68	23.03	22.04
Observations (n)	2,296		1,696		600	

10% significant level, ** 5% significant level, * 1% significant level. Standard errors (S.E.) are clustered at commune level. Monetary values are adjusted to the 2010 constant price. 44 households without any crop plots are excluded.*

Table A.4: Results of the sensitivity analysis on the numbers of plots, sizes of plots, irrigation, machinery use and labor allocation

	Two provinces			Ha Tay			Nghe An		
	n	**Coef.**	**S.E.**	**n**	**Coef.**	**S.E.**	**n**	**Coef.**	**S.E.**
Farm productivity									
All crops (Mil. VND/ ha)	2188	-1.10	6.19	1606	2.94	6.23	582	-10.23	9.49
Annual crop (Mil. VND/ ha)	2171	1.54	4.72	1595	0.31	6.60	576	1.44	2.70
Quantity of rice (ton/ha)	1710	0.27	0.64	1241	0.51	0.62	469	0.24	1.73

10% significant level, ** 5% significant level, * 1% significant level. Standard errors (S.E.) are clustered at commune level. Monetary values are adjusted to the 2010 constant price. 44 households without any crop plots are excluded.*

Table A.5: Results of the sensitivity analysis on farm productivity

References

Angrist, J. D. and Pischke, J. S. (2009). *Mostly harmless econometrics: An empiricist's companion*. Princeton University Press.

Bentley, J. W. (1987). Economic and ecological approaches to land fragmentation: In defense of a much-maligned phenomenon. *Annual Review of Anthropology* 16, 31–67.

Demetriou, D., Stillwell, J., and See, L. (2012). Land consolidation in Cyprus: Why is an integrated planning and decision support system required? *Land Use Policy* 29.1, 131–142.

Di Falco, S., Penov, I., Aleksiev, A., and Rensburg, T. M. van (2010). Agrobiodiversity, farm profits and land fragmentation: Evidence from Bulgaria. *Land Use Policy* 27.3, 763–771.

FAO (2018). *Small family farms country factsheet*. Food and Agriculture Organization of the United Nation.

Hung, P. V., Macaulay, T. G., and Marsh, S. P. (2007). The economics of land fragmentation in the North of Vietnam. *Australian Journal of Agricultural and Resource Economics* 51.2, 195–211.

Huynh, V. C. and Nguyen, T. D. (2013). Practices and impacts of land consolidation to agricultural and rural development in Phu Vang district, Thua Thien Hue province. *Vietnam Journal of Science and Development* 11.7, 1005–1014.

Jia, L. and Petrick, M. (2014). How does land fragmentation affect off-farm labor supply: Panel data evidence from China. *Agricultural Economics (United Kingdom)* 45.3, 369–380.

Kompas, T., Che, T. N., Nguyen, H. T. M., and Nguyen, H. Q. (2012). Productivity, net returns, and efficiency: Land and market Reform in Vietnamese rice production. *Land Economics* 88, 478–495.

Lai, W., Roe, B., and Liu, Y. (2015). Estimating the effect of land fragmentation on machinery use and crop production. *Agricultural and Applied Economics Association and Western Agricultural Economics Annual Meeting, San Francisco, CA, July 26-28*.

Manjunatha, A., Anik, A. R., Speelman, S., and Nuppenau, E. (2013). Impact of land fragmentation, farm size, land ownership and crop diversity on profit and efficiency of irrigated farms in India. *Land Use Policy* 31, 397–405.

Markussen, T., Tarp, F., Do, H. T., and Nguyen, D. A. T. (2016). Inter- and intra-farm land fragmentation in Viet Nam.

McPherson, M. F. (1982). Land fragmentation: A selected literature review. Development Discussion Paper No. 141.

Ministry of Agriculture and Rural Development (2002). Report to the Central Economic Committee of the Party on review of land policy and recommendation new points for revised Land law. Hanoi, Vietnam: Ministry of Agriculture and Rural Development.

Nguyen, H. Q. and Warr, P. (2020). Land consolidation as technical change: Economic impacts in rural Vietnam. *World Development* 127, 1–11.

Otsuka, K., Liu, Y., and Yamauchi, F. (2013). Factor endowments, wage growth, and changing food self-sufficiency: Evidence from country-level panel data. *American Journal of Agricultural Economics* 95.5, 1252–1258.

Pasakarnis, G. and Maliene, V. (2010). Towards sustainable rural development in Central and Eastern Europe: Applying land consolidation. *Land Use Policy* 27.2, 545–549.

Pingali, P. L. and Xuan, V. T. (1992). Vietnam: Decollectivization and rice productivity growth. *Economic Development and Cultural Change* 40.4, 697–718.

Rahman, S. and Rahman, M. (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.

Ravallion, M. and Van De Walle, D. (2008). *Land in transition: Reform and poverty in rural Vietnam*. The World Bank.

Research Institute of Agricultural Planning (2004). Analysis and recommendation solutions to solving land fragmentation in the Red River Delta, a report to the Ministry of Agriculture and Rural Development. Hanoi, Vietnam: Research Institute of Agricultural Planning.

Tan, S., Heerink, N., Kruseman, G., and Qu, F. (2008). Do fragmented landholdings have higher production costs? Evidence from rice farmers in Northeastern Jiangxi province, P.R. China. *China Economic Review* 19.3, 347–358.

Tarp, F. (2017). *Growth, structural transformation, and rural change in Viet Nam: A rising dragon on the move*. UNU-WIDER Studies in Development Economics: Oxford University Press.

Tran, T. D., Vo, N. V., Nguyen, T. H., and Truong, T. D. H. (2017). Efficiency of land consolidation program in Thang Binh district, Quang Nam province. *Journal of Vietnam Agricultural Science and Technology* 1.1, 47–54.

Vu, H. T. and Goto, D. (2020). Does awareness about land tenure security (LTS) increase investments in agriculture? Evidence from rural households in Vietnam. *Land Use Policy* 97, 1–10.

Wan, G. H. and Cheng, E. (2001). Effects of land fragmentation and returns to scale in the Chinese farming sector. *Applied Economics* 33.2, 183–194.

World Bank (2016). *Transforming Vietnamese agriculture: Gaining more from less*. The World Bank.

Yamauchi, F. (2014). Wage growth, landholding, and mechanization in agriculture: Evidence from Indonesia. Policy Research Working Paper; No.6789. World Bank, Washington, DC.

Zhang, J., Mishra, A. K., Hirsch, S., and Li, X. (2020). Factors affecting farmland rental in rural China: Evidence of capitalization of grain subsidy payments. *Land Use Policy* 90, 1–10.

Zhou, Y., Li, Y., and Xu, C. (2020). Land consolidation and rural revitalization in China: Mechanisms and paths. *Land Use Policy* 91.December 2019, 104379.