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What constrains mechanization in Chinese agriculture? Role of farm size and fragmentation

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ABSTRACT

Rising real wages create an incentive for relatively large landholders to increase their scale of operations allowing them to mechanize and save labor (or to allow farmers to work more off farm). Using panel data collected in 2000 and 2008 from 951 farm households in 6 provinces in China, the empirical analysis shows that (i) changes in the willingness to pay to rent in land is systematically related to real off-farm wage growth and the relationship depends on the initial farm size, and (ii) the introduction of machines to substitute for labor became active in the areas where real wages increased fast but was significantly constrained by land size per plot (and the number of plots), that is, land fragmentation. Our results imply that when real wages rapidly increase and labor shortage becomes serious, fragmented land holdings significantly constrain the decision to mechanize and consolidating fragmented lands can lead to higher efficiency through mechanization.

1. Introduction

An increase in real wages may induce a technical change to save labor or, simply, a substitution between labor and machines, i.e., mechanization, but also could lead to a new institutional arrangement that saves labor and/or reduces user costs of machines on farm with/ without land consolidation. Rosenzweig and Foster (2010) show some evidence to support the second point in India. Yamauchi (2016) also shows evidence from Indonesia that relatively large farms gain more efficiency in production by expanding their farm land and introducing machines. By using cross-country panel data, Otsuka, Liu and Yamauchi (2013) present evidence that if land markets are imperfect, new institutional mechanisms, for example machine service evolve to mitigate the efficiency cost attributed to the land market rigidities.

As real wages and thus the opportunity cost of farm labor rapidly increased, China that largely supports the proposition that wage growth in recent years led to an introduction of labor saving practices. Chinese farmers started relying on mechanical operations using machine services provided by the Specialized Custom Plowers, Planters and Harvesters (SCPPH) teams.

Consistent with the Hicks-Hayami-Ruttan-Binswanger hypothesis, the substitution of labor by mechanical operations appeared in all major crops as the relative price of labor to machine services dramatically decreased in the past decade (Wang et al., 2016). Earlier studies seemed to reach a conclusion that the availability of machine services is largely driven by supply side (Ji, Yu, & Zhong, 2012; Yang, Huang, Zhang, & Reardon, 2013). That is, prospective farmers tend to acquire more land by renting in land given the constraint

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of land sale market and also rely on machine services, rather than purchasing machines when real wages increase (Wang et al., 2016). In this sense, larger farmers are in a better position to expand the operational size, but the extent to which lands are fragmented potentially and significantly block mechanization. To overcome such a bottleneck, one of the most important rights in today's China is the rights to rent land (Deininger & Jin, 2005).[1] In almost all villages, households also have the rights to transfer land to another household or firm (Jin & Deininger, 2009). The existing literature have reached a concensus that one of the major functions of land rental markets is to reduce the extent to which lands are fragmented, i.e., renting in land from neighboring plots (Fleisher and Liu, 1992; Kung & Bai, 2011; Deininger, Monchuk, Nagarajan, & Singh, 2017).

In China, an effort has also been made to consolidate lands as evidenced by the emergence of more medium-sized farms who operate on a few hectares and large-sized farms who operate on tens and hundreds of hectares (Ji, Huang, & Gao, 2014). Cultivated land transfers have been accelerated since the late 2000s (MOA, 2014; Huang & Ding, 2016). By the end of 2013, nearly 53 million (or 23% of) rural households rented out their cultivated lands, which accounted for 26% of total cultivated lands under the household responsibility system (MOA, 2014).[2] Distinct from early common practices of transferring land among relatives and friends in village with nearly equal numbers of land rent-in and rent-out households (Gao, Huang, & Rozelle, 2012), land transfers moved to new operators in recent years. For example, in 2013, about 20% of rented-out land was transferred to farmers' professional cooperatives, more than 9% to companies, and the rest to individual households including newly-named “Family Farms” (MOA, 2014).[3]

Fragmented farm structures are costly in production and land consolidations have positive impacts on agricultural yield (Deininger et al., 2016). A number of studies focused on the impact of land fragmentation on agricultural production. Fleisher and Liu (1992) showed that land consolidation from 4 plots to 1 plot increased productivity (marginal product of labor) by 8%. Tan, Heerink, Kruseman, and Qu (2008) also showed that an increase of Simpson index by 0.01 has increased labor cost by 0.42% and decreased oxen and tractor cost by 0.33% in rice production. In Jia and Petrick (2014), an increase in the number of plots reduces agricultural output but only through the channel of labor productivity. Land consolidation does release rural labor. Other empirical works based on the analysis of household data also provide indirect and mixed evidence on the linkages between land fragmentation and labor supply in rural China. Wan and Cheng (2001) report a reduced on-farm labor demand under the scenario of land consolidation in maize and rice production. Furthermore, Carter and Yao (2002) found that more land parcels per farm reduce the average labor intensity on farm, which contradicts Tan et al. (2008). Benefits accruable from land consolidations are not just static but dynamic, e.g., through accelerated mechanization. However, the effect of fragmented lands on mechanization has not been directly evidenced.

This paper analyzes the roles of farm size and fragmentations in the introduction of mechanical operations using farm panel data collected in 6 provinces in China. Our hypothesis is rising real wages create an incentive for relatively large holders to increase its scale of operations to mechanize and save labor costs (substitute for labor), but fragmented lands may increase transaction costs to use machines as plots are separately located. In this setting, the decisions to increase farm/plot size and introduce mechanical operations (through machine services) are interdependent especially when real wages rise rapidly. This is exactly the situation in which fragmented lands matter in the substitution between labor and machines.

Rising real wages create an incentive for relatively large holders to increase its scale of operations to mechanize and save labor costs. In this sense, the decisions to increase farm size and introduce mechanical operations (through machine services) are interdependent. However, such mutually dependent decisions become important only when real wages are rapidly rising. Consistent with this conjecture, the empirical analysis shows that when agricultural wages rapidly increase, farm size becomes a critical factor to determine mechanization. Thus when real wage rapidly increases and labor shortage becomes serious in rural areas, large farms tend to gain its advantage to mechanize. However, the above scale merit is significantly penalized by land fragmentations captured by the number of plots. More consolidated lands seem to show advantage to introduce mechanization. In the literature it has been shown that in some economies when labor becomes more scarce and hired labor does not completely substitute the family labor, the households/individuals that remain in farming begin to specialize in order to more efficiently use their labor, farm more area and produce higher incomes (D'Antoni, 2014; Roumasset, Setboonsarng, Wickramasinghe, & Estudillo, 1995). Wang, Huang and Rozelle (2017) shows that off-farm employment including outmigration also leads to changes in farming systems. These shifts are characterized as changing subsistence farming to specialized activities in farming, according to the comparative advantages of the families that are left behind.

The analysis is complemented by the contingent valuation method applied to land rental transactions. The data on willingness to pay (WTP) to rent in land are used to disentangle farmers' willingness and actual decisions on land rental arrangements. The

[1] Land reform implemented in China since 1980s created a unique set of outcomes that differentiate itself from other transition economies (Deininger & Feder, 2001; Lin, 1992). Land rights for farming include a number of specific rights, including land ownership or alienation rights, land use rights and land contracting or transfer rights (Huang & Ding, 2016). In many cases these rights are separately endowed to different stakeholders. For example, land ownership rights remain the property of the collective (or the village). Villagers are unable to sell farm land to any individual. Land use rights are allocated by local cadres to every household within a village. Land use rights, by national policy, are bestowed to farmers for 30 years (from about 1998 to 2028). Recently, Chairman Xi (2017) delivered a report at the 19th National Congress of the Communist Party of China to declare that the land contract right will be extended to another 30 years after the expiration of the second round of land contract (around the year of 2028). The separation of land use rights and land contract rights from land ownership rights is one of the most innovative institutional changes in rural China. The importance of land contract, use and ownership rights has been discussed in a number of studies (Brandt, Huang, Li, & Rozelle, 2002; Brandt, Susan, Zhang, & Zhang, 2017; Huang & Wang, 2017; Kimura, Otsuka, Sonobe, & Rozelle, 2011; Liu, Carter, & Yao, 1998; Yao, 2000).

[2] Currently, we estimate that the shares of cultivated land in the state-owned farms, household responsibility system and village collectively reserved are about 5%, 93%, and 2%, respectively.

[3] While nearly all individual household-operated farms are family farms in China, to distinguish larger operational units from general household farms with small-scale land and to promote land consolidation, many provinces have set threshold sizes for farms to be Family Farms.

preliminary analysis shows that changes in the willingness to pay to rent and actual rental arrangements (decisions) are consistent. Interestingly, we observe that on average, farmers became more willing to pay to rent in land if real off-farm wages rapidly increased. This tendency is clear among those who operated relatively large land in the initial period. Interestingly, the relationship is negative among those who operated relatively small land. That is, large (small) farmers became more (less) willing to rent in when real wages increased fast, which is consistent with our conjecture on divergence among farmers.

The paper is organized as follows. Section 2 describes the data used in the analysis: household survey and experimental design on WTP. Empirical strategies are also described in Section 2. Section 3 presents empirical results. First, changes in the willingness to pay to rent in land is systematically related to real off-farm wage growth and the way they are related depends on the initial farm size consistently with our theoretical conjecture. Second, mechanization to substitute for labor became active in the areas where real wage growth was high but this was significantly constrained by the per-plot land size (and the number of plots). The above relationship is also clear among those who became more willing to rent in land.

2. Empirical framework

2.1. Household survey

The first wave of the data set was initially collected at the end of 2000 in 60 villages in six provinces. The first year of the data collection was based on surveys from 1199 households. These data were called the first wave of the China National Rural Survey and have been used in many studies of China's rural labor force (de Brauw, Huang, Rozelle, Zhang, Zhang, 2002; Zhang, de Brauw, Rozelle, 2004; Zhang, Zhang, Rozelle, Boucher, 2006; Mohapatra, Rozelle, Goodhue, 2007; de Brauw and Rozelle, 2008a and 2008b).

This study also used the data were collected in 2008 as the second wave of a panel dataset. The dataset includes information from 58 randomly selected villages in 6 provinces of rural China selected as representative of China's major agricultural regions. Henceforth, we call this dataset the 2008 China National Rural Survey, or 2008 CNRS dataset.

Both waves of the survey were focused on the same households in the same villages in the same provinces and the protocols during each of the waves were kept as similar as possible. The provinces are Hebei, Liaoning, Shaanxi, Zhejiang, Hubei, and Sichuan. In 2000 there were 60 villages and 1200 households. Unfortunately two villages were in the Sichuan earthquake zone and were damaged so heavily that a year after the earthquake most of the households had not returned to their normal lives in the village.

The selection of the sample was done carefully to make sure that we selected a sample that was representative of large areas of China. To reflect accurately varying income distributions within each province, one county was selected randomly from within each income quintile for the province, as measured by the gross value of industrial output. Two villages were selected randomly within each county. The sampled villages are mapped in Fig. 1. The survey teams used village rosters and our own counts to choose twenty households randomly, both those with their residency permits (*hukou*) in the village and those without. A total of 1160 households were surveyed (6 provinces × 5 counties × 2 villages × 20 households—minus the 40 households in two earthquake damaged villages in Sichuan).

Among the remaining 1160 households surveyed in 2000, we were able to re-investigate 1046 households in 2008. Of the 114 households that we could not find in the village, 89 had moved out of the village and were reported to be living in an urban area. The other 25 households either disappeared or were living in the village but were not engaged in farming activities (18 households—mostly because they were too sick to farm). With the missing information on the willing to pay for renting-in/out land, finally we have 952 households in the estimation. The descriptive statistics of the variables are presented in appendix Table A1.

2.2. Experimental design on WTP

The method of single-bounded discrete eliciting was designed to identify the WTP to rent in. The WTP questions are presented in Table 1. First, the enumerators asked the household (head) to identify the plot which they like to use in the experiment. For renting in, the process starts from the reference price at 300 yuan/mu. The scale (interval) of 100 yuan/mu was used. In WTPs to in, the upper bound is set at 600 yuan/mu in 2000 and 1000 yuan/mu in 2008. Agricultural tax and fee on the plot were ignored.[4][5]

For the WTP to rent in land, the interview went through a similar process starting from 300 yuan/mu. If the respondent responds "yes" at 300 yuan/mu, we then ask whether or not to rent in at 400 yuan/mu? If the respondent responds "not", the WTP to rent in is recorded as 300 yuan/mu. If the response to 300 yuan/mu was "no", we then ask whether or not to rent in at 200 yuan/mu. If the respondent responds "yes" at 200 yuan/mu, the WTP is 200 yuan/mu. Therefore, the interview continues until the response is "yes".

Fig. 1 shows the relationship between real off-farm wage growth (village-level) and change in the WTP to rent in (individual-level). Based on the sub-sample of farmers who operated larger than 2.5 mu (0.167 ha), we observe a positive relationship, which indicates that on average, an increase in off-farm wage induces relatively large farmers to be more willing to rent in to increase their scale of operations.[6] In contrast, if the operational size is less than 2.5 mu (0.167 ha), the relationship turns to negative, which implies

[4] 1 mu = 0.067 ha

[5] More detailed information about agricultural tax and fee could be found in Tao, Lin, Liu, and Zhang (2004).

[6] In this study, the average operational land was 7.22 mu (0.48 ha) and 7.30 mu (0.49 ha) in 2000 and 2008, respectively. However, the standard deviation of farm size has been increased from 8.43 mu in 2000 to 11.99 mu in 2008. This suggests that some of the farmers expanded the farm size. Our descriptive analysis shows that farm size was heterogeneous across provinces. In Hebei and Liaoning provinces, it was a bit larger than 1.5 times of the average operational farm size.

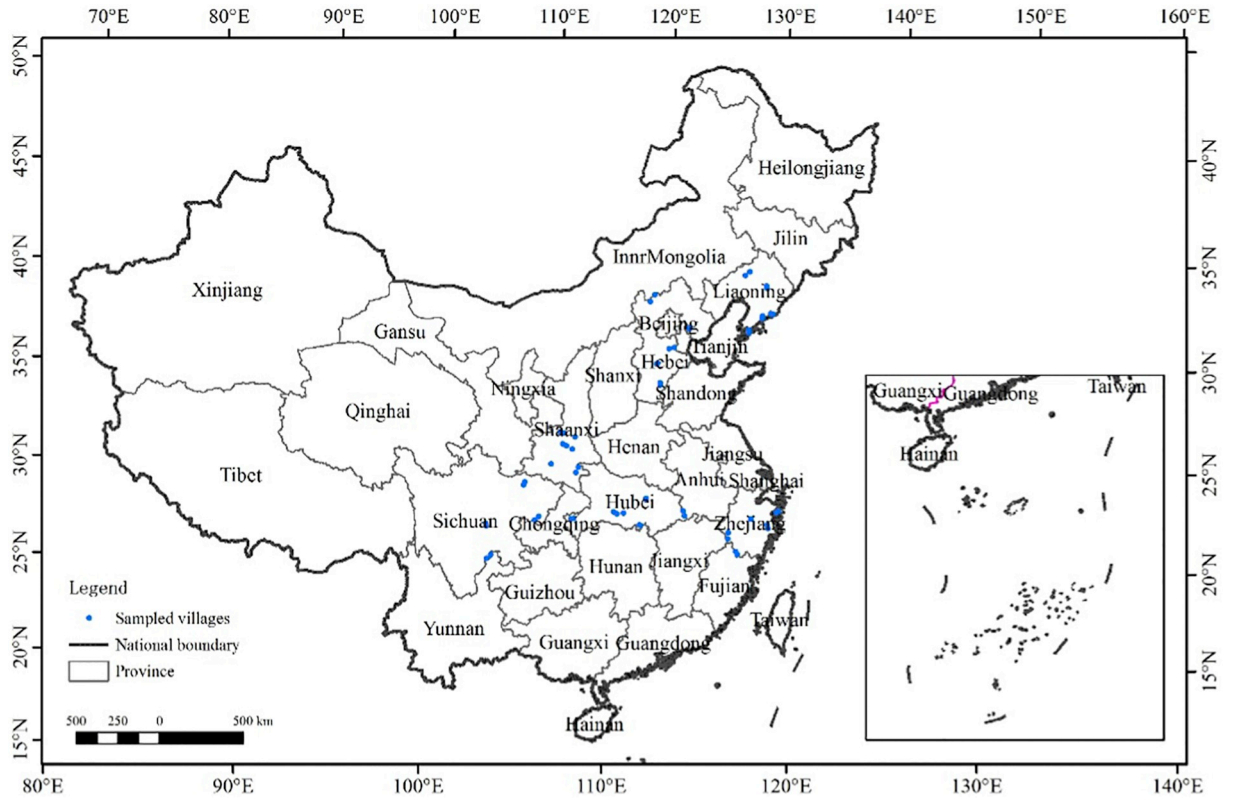


Fig. 1. The map of sampled villages

Table 1
Willingness to rent (contract) in land

Plot code	For the neighbored plot, If you don't need to bear any agricultural tax and fee and rent in for one year, are you willing to contract "in" the plot for the price listed below? (start from 300 yuan/mu, if willing, continue with 400-500 yuan/mu; if not willing, continue with 200-0 yuan/mu).					
	0	100	200	300	400	500	600

Note: The above questions were asked on the 1st plot of contract land

that relatively small holders tend to be less willing to rent in (they decrease their scale of operations). This observation is consistent with our conjecture since scale merits have to be realized if farmer intend to substitute for labor (in shortage) by machines and relatively larger farmers have such an advantage.

2.3. Empirical estimations

In the analysis of change in the expenses on machine services, the following first-differenced equation is estimated:

$$\Delta y_{ij(0,1)} = \alpha + \beta_1 land_{ij0} + \beta_2 frag_{ij0} + x_{ij0}\delta + vlg_j + \Delta\varepsilon_{ij(0,1)} \quad (1)$$

where $\Delta y_{ij(0,1)}$ is change in the expenses on machine services for household i in village j during the period between 2000 and 2008 (0 indicates the year of 2000 and 1 represents 2008), $land_{ij0}$ is the operational land size in 2000, $frag_{ij0}$ is a land fragmentation measure, which is either the per-plot land size, Simpson index or the number of plots in 2000.[7] x_{ij0} is a vector of the initial household and farm characteristics including family laborers and their education attainment, vlg_j is village fixed effects, and $\Delta\varepsilon_{ij(0,1)}$ is the difference in shocks (assume that ε_{ijt} is an ex-post shock after household decisions are made).

[7] There are several proxies of land fragmentation including Simpson index, the numbers of plots of land resource at household level (McPherson, 1982), the distance from plots to homestead, and per-plot land size. The simpson index is defined as follows: $SI = 1 - \Sigma_{i=1}{}^{n}\alpha_i{}^{2}/(\Sigma_{i=1}{}^{n}\alpha_i)^2$. Where n is the number of plots and $\alpha_i$is the area of each plot. The variable SI is the value between 0 and I, the higher the SI, the larger the degree of land fragmentation. The distance from plots is often endogenous with household production decisions in Chinas since the distance from plots to homestead are often considered as endogenous to land rental activities to expand the farm size. In this article, it is better to use either per plot land size or the number of plots as a proxy of land fragmentation. Thank for the comment from an anonymous reviewer.

The inclusion of village fixed effects is important in the above context to wipe out the machine price effect under the assumption that machine price is village specific. Logarithm transformation of machine expenses is decomposed into log of price and that of machine use (time). Therefore, change in log of machine expenses is linearly decomposed into price growth and machine use growth and the former is controlled by village fixed effects in the first difference specification.

The specification (1) only includes the initial conditions at the household level. The initial operational land size is an important conditioning variable in order to highlight the effect of fragmented lands. For instance, the per-plot land size and the total operational land size are included together, which essentially points to the role of fragmentation. If the former is significant (while the latter is not), fragmentation is an important constraint on mechanization decisions. In contrast, if the latter is significant (while the former is not), how the land is divided into plots does not matter in mechanization.

It is important to note that the specification (1) differs from the conventional form of first differencing since the key explanatory variables are the initial conditions, not first difference of those variables. This setting requires some cautions. For example, if the initial small landholding means that farmers tend to subsequently rent in more land, such an expansion of operational land may encourage the introduction of machines over time. Similarly, the initial land conditions are affected by unobserved factors including shocks and such factors are correlated with shocks to machine expenses, the parameter estimate could be potentially biased. However, since the land conditions are most likely predetermined prior to production activities, the initial-year shock to machine use is unlikely to be correlated with the initial land conditions.

Note also that potentially relevant unobserved factors affecting the initial landholding size and per-plot land size are similar by nature, which implies that, despite these potential caveats, a comparison of the estimated effects between the initial landholding size and per-plot land size would be meaningful to clarify relative importance of land-related bottlenecks influencing subsequent mechanization.

To check the effect of wage growth and (change in) WTP in the above framework, the sample is split into two regimes: (a) high wage-growth village and (b) low wage-growth (including negative growth) villages, and (a) farmers who became more willing to rent in and (b) farmers who became less willing to rent in. In the first case, the difference between (a) and (b) aims to clarify the effect of an increasing opportunity cost of farm labor on the roles of farm size and fragmentations in mechanization. The second case is based on individual-level differences in changes in the WTP to rent in, which is also related to changes in the opportunity cost of labor (see Fig. 2). However, an increase in real wages can encourage rent-in as well as rent-out depending on whether the household intends to expand farming (and mechanize to substitute for expensive labor) or migrate out of agriculture to earn in the labor market.

3. Empirical results

Empirical results are presented in this section. Table 2 presents the results on the initial land conditions on mechanization when real non-agricultural wages increase rapidly (Columns 1 to 4) and when the wages were stagnant (Columns 5 to 8). Thus, differences between the two tables are attributed to wage growth. Columns 1 to 4 use the sample of villages where real non-agricultural wage growth in 2000–2008 was higher than the sample average (75%).[8] The initial operational land size does not affect change in the expenses on machine services, but the per-plot land size does significantly (Column 1). In Column 2, the inclusion of squared term to incorporate non-linearity also shows that the operational size is not a significant determinant but the land size per plot matters (though with diminishing rate), which implies that, given the total size of operational lands, the degree to which the lands are fragmented is important.

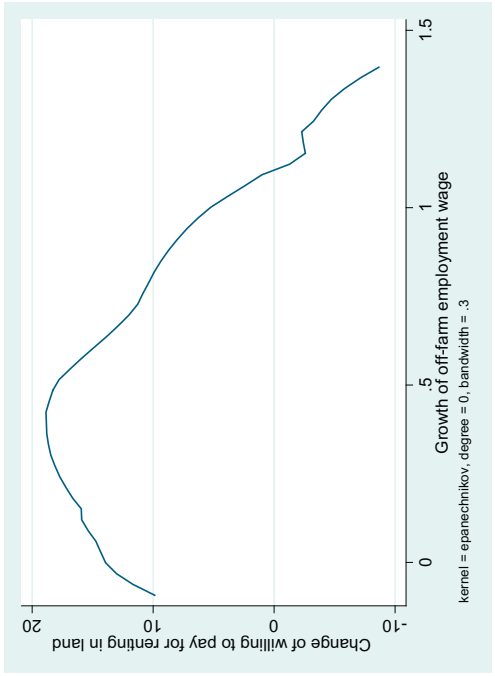
We also used Simpson index and the number of plots, but they are found insignificant in the above specifications. The preliminary analysis showed that the interaction of operational land size and the number of plots is significantly negative. Since the number of plots (fragmented lands) decreases the marginal effect of the total land size, its interpretation would be quite the same as the current version. However, the use of the per-plot land size does not require somehow complicated interaction terms.

Columns 3 and 4 include other household characteristics. The results remain robust even if other household characteristics are controlled. The average years of schooling are significantly negative, which means that additional investments to rent in land and mechanize are costly among relatively educated households since non-agricultural work opportunities are available to them. Regardless of the initial land conditions, more educated farm households tend not to introduce machines while they tend to probably work off farm more especially in the areas where real wages are increasing rapidly. This is also consistent with Wang et al. (2016b) that educated farmers tend to rent out their land.

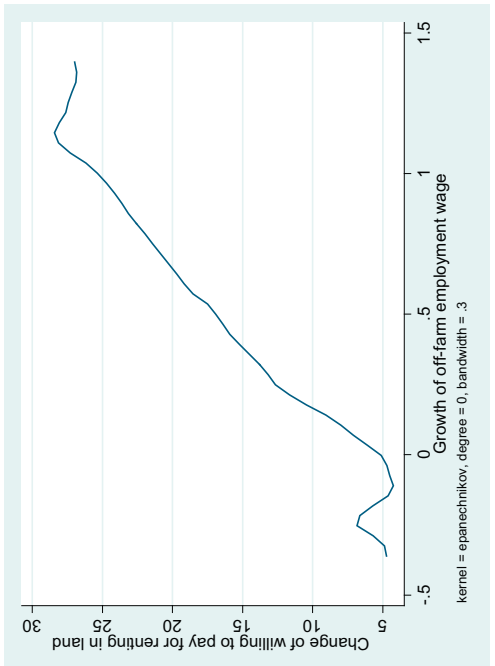
Columns 5 to 8 use the sample of villages where real non-agricultural wage growth is smaller than the sample average (75%). Though we see overall similarity of the parameter estimates between the two cases, the magnitude of the per-plot land size effect is much smaller in Columns 5 to 8. Moreover, in Columns 6 and 8 that include non-linearity, the operational land size effect is negative (convex) while the per-plot land size effects are small but significantly positive.[9] Overall, the above findings imply that (i) land

[8] Wage rates used in this study are the average non-agricultural wages in a village. This is for all off-farm workers in a village (yuan/h), which is expected to reflect the opportunity cost of farm work in the local economy. Note that workers can find off-farm jobs not only in their village but also in the local economy outside the village. Here, all of the value terms are adjusted at 2000 constant price using provincial CPIs. Our data show that hourly non-agricultural wages doubled from 1.92 yuan/h (0.23 US$/h) in 2000 to 4.00 yuan/hour (0.48 US$/hour) in 2008. The cut-off of two regimes is the mean of the real wage growth rate from 2000 to 2008.

[9] In Columns 6 and 8, the marginal effect is negative at the mean and within a reasonable range of operational land size. The linear effect is not significant probably because of convexity picked up by the square term, but the marginal effect is consistently negative. In contrast, the effects of land size per plot are positive and significant in all specifications.



b. Farm size < 2.5 mu



a. Farm size > 2.5 mu

Fig. 2. The correlation between the growth of off-farm employment wage and change of willing to pay for renting in land

Table 2
Growth of machine service in the two scenarios of opportunity cost of labor in agricultural production.

Dependent variable: Growth of machine service (yuan)								
	High real wage growth				Low real wage growth			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Operational land (2000)	-0.0653	-0.0859	-0.0620	-0.0790	0.0358	-0.1658*	0.0492	-0.1297
	(1.14)	(0.57)	(1.02)	(0.48)	(0.60)	(1.94)	(0.93)	(1.58)
Operational land^2		0.0003		0.0003		0.0024***		0.0020***
		(0.18)		(0.15)		(3.26)		(3.01)
Per-plot land (2000)	0.0123***	0.0549***	0.0121***	0.0540***	0.0041**	0.0095**	0.0038**	0.0092**
	(8.20)	(5.79)	(8.66)	(5.78)	(2.30)	(2.64)	(2.13)	(2.37)
Per-plot land^2		-0.0000***		-0.0000***		-0.0000*		-0.0000*
		(4.59)		(4.64)		(1.85)		(1.72)
Number of labor (2000)			0.0679	0.0429			-0.1373	-0.0474
			(0.23)	(0.14)			(0.53)	(0.18)
Number of female labor (2000)			-0.1589	-0.1437			-0.2931	-0.2373
			(0.46)	(0.42)			(1.14)	(0.88)
Age (labor, 2000)			-0.0120	-0.0098			0.0270	0.0237
			(0.28)	(0.24)			(1.04)	(0.96)
Years of schooling (labor, 2000)			-0.2349**	-0.2306**			-0.0046	-0.0115
			(2.17)	(2.13)			(0.04)	(0.10)
Constant	1.7369***	1.7632*	3.5031	3.4566	1.3320***	2.2734***	0.8310	1.5531
	(3.69)	(1.79)	(1.41)	(1.31)	(3.79)	(5.18)	(0.68)	(1.35)
Village fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
No. of obs.	444	444	444	444	507	507	507	507
R-sq	0.025	0.031	0.034	0.040	0.017	0.040	0.025	0.043

Source: Authors' own data.
Note: Parentheses show absolute t values using robust standard errors with province clusters.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

fragmentation is an important factor that determines mechanization, but also that (ii) the negative (marginal) effect of land fragmentation is larger when real wages increase rapidly, i.e., land fragmentation becomes a critical constraint on mechanization under such a circumstance.

We also use change in the WTP to rent in to split the sample (Table 3). Fig. 1 showed that change in the WTP to rent in is positively associated with real wage growth especially among relatively large holders. Columns 1 to 4 use the sample of farmers (not villages) who became more willing to pay to rent in.[10] The results in Table 3 resemble that of Table 2, which implies that for those who are more willing to rent in and aim to realize scale economies, the initial land conditions especially the degree to which lands are fragmented became more important in the decision to use machine services. In contrast, for those who became less willing to rent in, the linkage between the initial land conditions and mechanization was not clear (Columns 5 to 8). Interestingly, the contrast between the two cases (i.e., Columns 1–4 and Columns 5–8) is much sharper in Table 3 probably because the household-level heterogeneity related to the initial holding matters in the decision making on mechanization (see Fig. 1).

4. Conclusions

Rising real wages create an incentive for relatively large holders to increase the scale of operations to mechanize and save labor costs. The empirical analysis of this paper has supported this proposition, but also shown that the initial land endowment conditions also become important constraints. In particular, the results clearly showed that when agricultural wages rapidly increase, per-plot land size becomes a critical factor to determine mechanization. That is, the scale merit is significantly penalized by land fragmentation. Wang et al. (2016b) showed that large farmers are in a better position to rent in more land when real wages rapidly increase and therefore can have a scale advantage to mechanize. Our paper contributes to the literature by showing that how the land is divided into plots matters at least equally significantly. That is, consolidating plots to form a larger operational plot leads to more efficient substitution for labor by machines.

[10] We calculate the price of willing to rent in land in 2000 and 2008 at 2000 constant price. The regime of more willing to rent in land is defined as the changed price of willing to rent in land increased from 2000 to 2008 while the other regime is that the changed price of willing to rent in land decreased from 2000 to 2008.

Table 3
Change in machine service in the two scenarios of farmers' willing to pay for renting in land.

Dependent variable: Growth of machine service (yuan)								
	More willing to rent in				Less willing to rent in			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Operational land (2000)	0.0048	-0.1725**	0.0135	-0.1545*	0.0292	0.0216	0.0244	0.0137
	(0.08)	(2.24)	(0.25)	(1.93)	(0.47)	(0.17)	(0.37)	(0.10)
Operational landˆ2		0.0022***		0.0020***		0.0003		0.0004
		(3.17)		(2.87)		(0.14)		(0.15)
Per-plot land (2000)	0.0087***	0.0212***	0.0086***	0.0229**	0.0025*	0.0100*	0.0020	0.0088
	(4.70)	(2.69)	(4.23)	(2.59)	(1.71)	(1.88)	(1.44)	(1.48)
Per-plot landˆ2		-0.0000		-0.0000*		-0.0000*		-0.0000
		(1.65)		(1.69)		(1.76)		(1.42)
Number of labor (2000)			-0.0962	-0.0168			0.2085	0.2100
			(0.43)	(0.07)			(0.84)	(0.84)
Number of female labor (2000)			-0.2672	-0.2112			0.1585	0.1628
			(0.96)	(0.73)			(0.55)	(0.56)
Age (labor, 2000)			0.0058	0.0018			0.0122	0.0118
			(0.20)	(0.07)			(0.37)	(0.36)
Years of schooling (labor, 2000)			-0.1531	-0.1693			-0.1593	-0.1579
			(1.43)	(1.66)			(1.53)	(1.51)
Constant	1.0445**	2.0002***	2.1029	3.0191*	1.3558***	1.3415**	1.2171	1.2193
	(2.45)	(4.10)	(1.27)	(1.97)	(3.66)	(2.23)	(0.64)	(0.60)
Village fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
No. of obs.	650	650	650	650	601	601	601	601
R-sq	0.024	0.041	0.032	0.048	0.004	0.008	0.012	0.015

Source: Authors' own data.
Note: Parentheses show absolute t values using robust standard errors with province clusters
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

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Appendix A. Appendix

Table A1
The descriptive statistics of the variables by the group of the opportunities cost of the labors.

Variables	Growth of wage > mean		Growth of wage < mean	
	Mean	Std. Dev.	Mean	Std. Dev.
Change in rented in land (mu)	0.460	(3.919)	0.248	(4.189)
Change in the expense of machine service (yuan)	76.255	(302.035)	68.913	(240.170)
Operational land in 2000 (mu)	8.222	(9.425)	5.956	(7.320)
Per-plot land in 2000 (mu/plot)	1.882	(1.704)	1.508	(2.004)
Number of labor (2000)	2.744	(1.038)	2.808	(1.043)
Number of female labor (2000)	0.565	(0.760)	0.703	(0.919)
Age (labor, 2000)	38.627	(8.656)	38.626	(8.592)
Years of schooling (labor, 2000)	6.189	(2.613)	6.119	(2.586)
No. of observations	444		507	

Source: Authors' own data.

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