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How does land fragmentation affect off-farm labor supply: panel data evidence from China

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How land fragmentation affects off-farm labor supply in China: Evidence from household panel data

Abstract

This paper provides a deeper theoretical understanding of the linkages between land fragmentation and off-farm labor supply in China, and investigates this relationship empirically in a more direct way than does the existing literature. Drawing upon a rural household panel dataset collected in Zhejiang, Hubei and Yunnan Provinces from 1995-2002, we estimate the effects in two steps. First, we estimate the effect of land fragmentation on labor productivity. Second, we estimate the effect of land fragmentation on off-farm labor supply. The production function results show that land fragmentation indeed leads to lower agricultural labor productivity, implying that land consolidation will make on-farm work more attractive and thus decrease off-farm labor supply. However, the effect of land consolidation on off-farm labor supply cannot be observed. One explanation for this result may be the potentially imperfect labor markets.

Keywords: Land fragmentation, off-farm, labor supply, China.

JEL codes: J22, Q15, Q24, R23.

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1 Introduction

Research on agricultural development in China has increasingly examined the potentially negative effects of highly fragmented farm structures.[1] Various researchers point out that land fragmentation is causing productivity losses (Nguyen et al., 1996; Wan and Cheng, 2001; Chen et al., 2009). Thus, land fragmentation has direct implications for the Chinese government's goal of fostering productivity levels in domestic agriculture. However, changes in land fragmentation may also have consequences for input use in agriculture. Aside from land, the most important input in Chinese agriculture is labor. Based on an analysis of labor costs in Chinese farm households, Tan et al. (2008) suggest that more liberal land policies allowing consolidation may release more agricultural surplus labor in the future. If this is true, policies addressing land fragmentation will also affect the steadily increasing number of off-farm employees and rural migrants, which is one of the most challenging problems of the Chinese economic transition.

While Tan et al. (2008) find that fragmented farm structures correlate with higher labor costs, it is not clear why this implies that land consolidation releases rural labor, as the authors do not investigate the actual mechanisms of labor allocation. Moreover, other empirical work based on the analysis of household data provides only indirect and mixed evidence on the linkages between land fragmentation and off-farm labor supply in rural China. Wang et al. (2007) found positive effects of village land renting activities, which implies a higher potential for voluntary land consolidation, on household decisions to participate in the off-farm labor market in Zhejiang Province. This evidence supports the suggestion by Tan et al. (2008), that fragmented farm structures correlate with higher labor costs. However, Wang found no effect on the quantity of households' off-farm labor supply. Wan and Cheng (2001) report that more plots per household increase the marginal product of labor in maize and early rice production[2] , thus implying a lower on-farm labor demand if land is consolidated. However, they found the opposite for tuber production. Furthermore, in a sample of farmers from Jiangxi and Zhejiang Provinces, Carter and Yao (2002) found that more land parcels per farm reduce the average labor intensity on-farm, which contradicts Tan et al. (2008). Similarly, Brosig et al. (2007) show that, in Zhejiang villages with much activity on the land rental market, households display a lower tendency to engage in off-farm labor markets.

In this article, we aim to acquire a deeper theoretical understanding of the linkages between land fragmentation and off-farm labor supply, and investigate this relationship empirically in a more direct way than does the existing literature. Our theoretical argument is that whether or not land consolidation releases agricultural labor depends on the local shape of the production function and is undetermined *a priori*. We develop this argument in the framework of a microeconomic farm household model and show that the critical parameter is the effect of land fragmentation on the marginal product of labor. We

[1] Land fragmentation means that a household's land resources are divided in several spatially-separated plots (McPherson, 1982). In China, this emerged as a result of the egalitarian land redistribution in the aftermath of the Household Responsibility System (HRS), which was implemented in the late-1970s and early-1980s (Tan et al., 2006).

[2] The estimated β_2 parameters in table 5 of their paper.

then employ a panel set of household data from three Chinese provinces to investigate this issue econometrically. Our empirical strategy consists of two steps. We first estimate the effect of land fragmentation on labor productivity by using a flexible, aggregate production function. We then estimate a labor supply function and test the direct influence of land fragmentation on off-farm labor supply. The available panel data allows us to eliminate unobserved heterogeneity by employing fixed-effects techniques, which we adapt to be used in a flexible production function. The effects of the potential endogeneity of labor allocation are considered. In estimating the off-farm labor supply equation, we employ a panel data sample selection model following Wooldridge (1995) that allows us to address problems of unobserved heterogeneity and sample selectivity simultaneously, which has not yet been done in the agricultural household literature.

We replicate the conventional wisdom that fragmentation reduces output and hence implies productivity losses. However, we also show that the negative effect of fragmentation on labor productivity is the only channel through which such output reduction occurs. A direct implication is that land consolidation will make on-farm work more attractive and thus decrease off-farm labor supply. However, the effect of land consolidation on off-farm labor supply cannot be observed. One explanation for this result may be the potentially imperfect labor markets.

If an increased reliance on voluntary land transactions and the gradual hardening of individual property rights in land markets allow more land consolidation in the future, this will not lead to a flood of labor-seeking migrants from rural areas to cities. Instead, agricultural labor productivity will increase and farming will become a more attractive occupation.

This paper is structured as follows: first, we analyze the effect of land fragmentation on agricultural labor productivity and off-farm labor supply using a theoretical approach. Second, we discuss the sources of land fragmentation in China. Third, we present the empirical methodologies used to estimate these effects. Fourth, we introduce the database. We then report the results, and finally we discuss the results and conclude.

2 Theoretical analysis of the effects of land fragmentation

2.1 The effect of land fragmentation on agricultural labor productivity

We consider a separable farm household model with land fragmentation. The model follows the standard model as presented by Benjamin (1992), but is augmented by a land consolidation parameter, α, that determines how effectively labor can be used on the land.

We first outline the standard model. The farmer maximizes utility by choosing consumption, c, measured by monetary unit and leisure time, l, subject to a set of household characteristics, a, for example, its demographic composition. The household allocates family labor, L, to produce an aggregate agricultural output, Y. There are other fixed inputs, A, so that $Y = Y(L; A)$, with $Y_1 > 0$ and $Y_{11} < 0$. The household may also supply labor off-farm, L^O, which yields an exogenously determined wage, w. Total time endowment is $T(a)$. To simplify the exposition, we ignore the possibility that labor may also be hired. Hence, the farmer's problem is as follows:

(1) $\max u(c,l;a)$ w.r.t. c,l,L^O,L s.t.

(2) $c = Y(L;A) + wL^O$,

(3) $l + L + L^O = T$.

In this model with an exogenous wage, profits are maximized independent of the household's utility function. The optimal amount of labor supplied on the farm depends only on the production technology and the wage, following the optimality condition $Y_1 = w$. Given the leisure choices of the household l, which depend on a, off-farm labor supply, $L^O \geq 0$, is determined as a residual. This is shown in Figure 1 (a).

We now introduce an exogenous land consolidation parameter, $\alpha \in]0,1]$, which measures the efficiency of labor use on the plot. If α is close to 1, almost all the time allocated to farming is actually spent on the plot. If α is closer to 0, much time is used for traveling to and from the plot, or for other unproductive activities that result from land fragmentation, such as cumbersome water management or less efficient machinery use (Wan and Cheng, 2001). Hence, the amount of labor productively used is reduced. We write $Y = Y(\alpha L;A)$ in the presence of land fragmentation, where αL is the level of effective on-plot labor. As an illustration, consider that L is measured in days spent on-farm, each day covering 10 working hours. If $\alpha = 0.8$, the household spends 2 hours per day on traveling and other non-productive activities, and 8 hours effectively on the plot. If the household chooses to spend many days on-farm, the absolute time spent non-productively will also increase proportionally.

We are interested in the effects of varying α on labor use in the household. If land fragmentation is modeled in the abovementioned way, the first point to note is that more fragmented land unambiguously reduces output. To see this, consider the effect of land fragmentation on output as follows:

(4) $$\frac{\partial Y}{\partial \alpha} = \frac{\partial Y}{\partial \alpha L} L .$$

With $Y_1 > 0$, this effect is unambiguously positive, which implies a negative impact of fragmentation on the absolute level of output.

Secondly, note that *the effect of land fragmentation on the marginal product of on-farm labor is undetermined*. The marginal productivity of labor (MPL) in the model with land fragmentation is given as follows:

(5) $$\frac{\partial Y}{\partial L} = \alpha \frac{\partial Y}{\partial \alpha L}.$$

The effect of α on the MPL is then:

(6) $$\frac{\partial^2 Y}{\partial L \partial \alpha} = \frac{\partial Y}{\partial \alpha L} + \alpha L \times \frac{\partial^2 Y}{\partial (\alpha L)^2} .$$

The first term on the right-hand side denotes the marginal product of effective on-plot labor on output, which is positive given our assumptions on technology and profit maximization. The second term is the effective labor on-plot input, which is non-negative according to our assumption. The third term is the second derivative of the production function with regard to effective labor input, which is negative given our concavity

assumption, $Y_{11} < 0$. Hence, a negative number is added to a positive one, so that the sign of the composite is theoretically undetermined[3].

2.2 The effect of land fragmentation on off-farm labor supply

Now we turn to the consequences of land fragmentation on off-farm labor supply. The reduced form off-farm labor supply equation derived from the above model is as follows:

$$L^O = L^O(w, a, A, \alpha). \tag{7}$$

The level of L^O is given by $L^O = T - l - L$, so that:

$$\frac{\partial L^O}{\partial \alpha} = -\frac{\partial l}{\partial \alpha} - \frac{\partial L}{\partial \alpha}. \tag{8}$$

The effects of land fragmentation on off-farm labor supply depend on the effects of land fragmentation on leisure time and on-farm time, since the household is subject to a total time endowment constraint. When the effect of α on the MPL is undetermined, we do not know *a priori* whether the household will employ more or less labor on-farm as a result of varying land fragmentation. *The effect of land fragmentation on off-farm labor supply is hence also undetermined.*

In equation (8), the plausible hypothesis will be that $\frac{\partial l}{\partial \alpha} > 0$, implying that richer households consume more leisure (as depicted in Figure 1 (b) and (c)). When land consolidation decreases on-farm employment, and an increase of leisure time does not exceed the decrease of agricultural work, land consolidation will promote the off-farm labor supply (Figure 1 (b)). Conversely, when land consolidation results in an increase of on-farm employment without hiring laborers, off-farm labor supply will be reduced, as depicted in Figure 1 (c).

2.3 Potential sources of labor market imperfections

Numerous authors have pointed out that the assumption of a perfect labor market is a strong one in many empirical settings, including China (Benjamin, 1992; Benjamin and Brandt, 2002; Bowlus and Sicular, 2003; Wang et al., 2007). For example, there may be an exogenously imposed upper bound to the number of hours a household can find employment at the going market rate, and this bound may be lower than the actual labor supply. There are several plausible reasons for such constraints in the Chinese context. In addition to a simple lack of jobs in rural areas, rural inhabitants may not possess the necessary education for off-farm employment (Yang, 2004), the allocation of jobs by village leaders may be based on non-market, political and social criteria such as family connections or household income (Bowlus and Sicular, 2003), or farm households working off-farm may fear the loss of their rights to land use (Kung, 2002b; Wang et al., 2011). In such cases of off-farm labor rationing, the separability property of the model breaks down.

Following Benjamin (1992), the labor allocation for agricultural households is depicted in Figure 2. When there are constraints on the labor supply side, the agricultural households

[3] A numeric simulation demonstrating this point is available from the authors upon request.

can only supply a fixed amount of off-farm labor, for example L^O. The optimal on-farm labor input is no longer at point A, but rather at point C in Figure 2, and the on-farm wage is the shadow wage, which is lower than the off-farm wage. In this case, the land consolidation does not affect off-farm labor supply anyway. If in the extreme there is no off-farm employment opportunity at all, land consolidation will fail to affect observed off-farm employment. It is rather likely to increase the amount of leisure time and/or somewhat reduce hidden unemployment, depending on the household's preferences for leisure (or home time) consumption (Brooks and Tao, 2003; Ho et al., 2004). If off-farm work is possible at some wage, this wage may nevertheless be endogenous and dependent on household characteristics (Sumner, 1982; Skoufias, 1994). Estimations of empirical labor effects should take this potential endogeneity into account.

3 Main sources of land fragmentation in China

Land institutions and land rental markets are the key channels to shift the degree of land fragmentation. In China, land fragmentation emerged in the aftermath of the Household Responsibility System (HRS), which was implemented in the late-1970s and early-1980s. According to this system, farmland in the village is categorized into several classes and equally distributed to each household. Land reallocations happen from time to time since the rural land is collective and the farmers only have quasi-private property rights (Kung, 2002a). According to Rozelle and Li (1998), more than 60% of villages reallocated land at least once after the implementation of HRS. However, the decision-making of land reallocation is heterogeneous among villages. Dong (1996) suggests that the central government plays an important role in determining land reallocation. Whereas other researchers argue that the village leaders are the key to land reallocations in villages due to their rent-seeking activities, protecting their own interests, minimizing administrative costs in villages, and concerns of improving equity and efficiency (Rozelle and Li, 1998; Brandt et al., 2004; Brandt et al., 2002). In addition, Kung (2000) found that land reallocation in China might also come at the request of villagers. As reported in Kung's survey, 42.7% of land reallocations in villages were attributed to population change, 24.4% to the requests of villagers, another 24.4% to higher administration instruction, 4.9% to the transfer of labor force out of agriculture, 2.4% to enlarging farm size, and only 1.2% to land fragmentation. Thus, the influence of land fragmentation on land reallocation in China is so limited that it can be disregarded.

On the other hand, the emerging land rental market in China provides a more efficient way to adjust plots (Deininger and Jin, 2005). Land renting has been officially approved in China since 1998 and was strengthened in 2002 and 2008, which provided farmers more freedom to adjust their plots (Deininger and Jin, 2009; Wang et al., 2011). However, a large body of evidence shows that the land rental market is depressed by insecure land rights, and farmers could not reduce land fragmentation systematically through the land rental market (Liu et al., 1998; Li et al., 1998; Zhang et al., 2011; Carter and Yao, 2002; Yao, 2002; Deininger and Jin, 2009). Although trading plots is possible, it is very unlikely for farmers to reduce land fragmentation systematically through the land rental market. Our data indicate that only 78 observations (households in a specific year) out of 12,104 (accounting for only 0.6%) successfully consolidated their land by exchanging

plots through the land rental market. It is thus plausible to consider land fragmentation as exogenous in this paper.

4 Empirical methodology

4.1 The effect of land fragmentation on agricultural labor productivity

A first aim of the econometric analysis in this paper is to provide an unbiased estimate of the effect of land fragmentation on labor productivity, and hence an estimate of equation (6). The strategy used here is to estimate a flexible production function that takes into account the number of plots per farm, N , as a measure of land fragmentation.[4] As summarized by Deaton (1995, 1824-1827), estimating production functions from micro data involves a number of econometric challenges that are discussed in the following, together with their potential remedies.

Previous studies have used Cobb-Douglas (CD) production functions to estimate the impact of land fragmentation (Fleisher and Liu, 1992; Nguyen et al., 1996). To estimate a partial effect of land fragmentation on MPL, a more flexible approach is needed that allows interactions among factors. Similar to Wan and Cheng (2001), we employ a translog function, which extends the CD by both interaction and square terms of the factors.

Given the three conventional inputs, plus the number of plots as arguments, the translog function with land fragmentation can be expressed as follows:

[4] In this paper, we define land fragmentation as a household's land resources that are divided in several partially separated plots (McPherson, 1982). There are also many measurements for land fragmentation such as the Simpson index, the distance from plots to homestead, the number of plots and per plot size. The Simpson index is defined as follows:

$$SI = 1 - \sum_{i=1}^{n} \alpha_i^2 / (\sum_{i=1}^{n} \alpha_i)^2$$

where n is the number of plots and α_i is the area of each plot. The variable SI is the value between 0 and 1, the higher the SI, the larger the degree of land fragmentation. In principle, this is a more accurate approach for measuring degree of land fragmentation. The more plots the farmers have, the more time they will spend on traveling among the plots, which directly influences agricultural labor productivity. The Simpson index cannot be calculated due to a lack of data. Also, the distance from plots to homestead is an important indicator, but the average distance from plots is often endogenous with household production decisions in China since the distances from plots to homestead are often considered in both land allocations and land renting activities. In this paper, it is better to use either the number of plots or per plot size as a proxy. Former research reveals that land fragmentation mainly results from a waste of labor due to extra traveling between plots and homestead (Tan et al., 2008; Wan and Cheng, 2001). Therefore, the number of plots on a farm is the most direct and efficient measurement for degree of land fragmentation for analysis in this paper.

$$\begin{aligned}\ln Y_{it} &= \beta_0 + \beta_1 \ln L_{it} + \beta_2 \ln K_{it} + \beta_3 \ln A_{it} + \beta_4 \ln N_{it} + \beta_5 \ln N_{it} \ln L_{it} \\ &+ \beta_6 \ln N_{it} \ln A_{it} + \beta_7 \ln A_{it} \ln K_{it} + \beta_8 \ln L_{it} \ln K_{it} + \beta_9 \ln N_{it} \ln K_{it}, \\ &+ \beta_{10} \ln L_{it} \ln A_{it} + \frac{1}{2}\beta_{11}(\ln L_{it})^2 + \frac{1}{2}\beta_{12}(\ln K_{it})^2 + \frac{1}{2}\beta_{13}(\ln A_{it})^2 + \frac{1}{2}\beta_{14}(\ln N_{it})^2 + u_{it}\end{aligned} \tag{9}$$

where u_{it} is an identically and independently distributed (i.i.d.) error term, K indicates all capital input such as fertilizer, pesticide and diesel inputs. Therefore, N is allowed to affect all marginal products of inputs. By using the output price as an aggregation device, we obtain the total output, Y.

The direct effect of land fragmentation on agricultural production is β_4, which is supposed to be negative according to equation (9). Nguyen et al. (1996) and Wan and Cheng (2001) report regression estimates that support this assumption. If $\beta_4 = \beta_5 = \beta_6 = \beta_9 = 0$, land fragmentation has a zero impact on the marginal product of inputs; otherwise, the impact of land fragmentation is undetermined. The effect of land fragmentation on labor is β_5, which will be determined by the local shape of the production function. When β_5 is positive, it indicates that the MPL on fragmented land is higher than that on consolidated land at the same amount of every input. When β_5 is negative, it indicates that the MPL on fragmented land is lower. As this parameter is of prime interest in our analysis, we attempt to estimate equation (9) in the following.[5]

A common problem with estimating production functions from observational data is that individual farm output may be affected by unobserved characteristics of the farm. These characteristics may be due to "management bias" as introduced to the literature by Mundlak (1961), or may reflect socio-demographic or geographic characteristics of the farm that are constant over time. For example, soil fertility, farmers' management ability and technology are supposed to be correlated with inputs. If panel data is available, as it is in our case, the typical way to eliminate the influence of these factors is to use a fixed-effects (FE) or "within groups" estimator. However, an ordinary FE model depends on the assumption of linear additivity and fails to eliminate the level effect in the presence of interaction terms (Angrist and Pischke, 2009, 222). To control for time-invariant heterogeneity in our translog model, we use time-demeaned Ordinary Least Square (OLS) regression (Wooldridge, 2009, 481) to estimate equation (9). Rather than simply adding household-specific dummy variables to the estimating equation as in the standard FE

[5] A commonly used approach in the literature is to estimate agricultural technology based on a dual specification. Sometimes, the production function is taken as a starting point, but more frequent is the use of profit or cost functions (Capalbo, 1988). Estimation is typically based on the derived set of input share equations, which will depend on input quantities in the case of a production function, and on input prices and output quantities or prices in the cases of cost and profit functions (see Capalbo, 1988 for a summary, and Berndt, 1991, chapter 9, for further technical detail and literature). As we are interested in recovering the parameter β_5 of the production function in (9), dual specifications of profit or cost functions that do not include this parameter are of little help. While a modified system of share equations dependent on input quantities may be used to provide an estimate of this parameter, it does not solve the endogeneity problems discussed below. Furthermore, it requires the calculation of cost shares for all inputs, which in our case is prohibited by lacking data, particularly for labor and land. It is unclear how fragmentation could be included in such an approach. We therefore resort to estimating (9) in a direct, primal manner. See Mundlak (2001) for critical remarks on the dual approach to estimating production technology.

approach, all variables were first groupwise time demeaned and then interacted. In addition, year dummies for every year except 1995 were added.

An additional concern in primal estimations of production functions is the endogeneity of inputs (Deaton 1995, 1824). While variations in output may well be explained by variations in inputs on statistical grounds, the concern is that this correlation may be spurious and not due to an appropriately specified causal effect. Hence, the independence portion of the i.i.d.-assumption is violated. In equation (9), the amount of land and number of plots can be assumed to be exogenous due to restrictions of the Chinese land market. Capital input is regarded as exogenous in our estimation for both simplification and concentration. Labor input is most likely to be an endogenous variable for the various reasons mentioned above. To the extent that the omitted factors are time invariant, our FE approach yields unbiased estimates of the causal effect. We also experimented with instrumenting the labor variables used in equation (9); however, due to a lack of suitable instruments, this did not yield useful results. Even so, we consider the likely direction of the endogeneity bias in the production function below.

To ease the interpretation of coefficients in the translog model, geometric sample means were subtracted from all variables after taking logs, so that the estimates of β_1 to β_4 are the production elasticities of the factors at geometric sample means.

A common problem with analyzing microdata is that observations come from clustered samples, for example many households come from the same village. This is also the case in our current sample, as described in the data section. Deaton (1997, 73-78) argues that standard errors are too small if the conventional formula is applied, because the "identical" part of the i.i.d.-assumption is violated. Following White (1984), some correction for this heteroscedasticity based on the cluster-specific regression residuals is suggested. Related results are reported in the following.

4.2 The effect of land fragmentation on off-farm labor supply

In a second step, we aim to estimate the off-farm labor supply equation to identify the fragmentation effect in equation (8). The off-farm labor supply is a projection of off-farm wage and other demographic variables that can be specified as follows:

$$L_{it}^{o} = \delta_0 + \delta_1 w_{it} + \delta_2 x_{it} + v_i + u_{it}, \qquad t = 1,.....,T,\ i = 1,.....,n \tag{10}$$

where x_{it} includes all the other independent variables except for the off-farm wage w_{it} (such as the number of plots as a measure of land fragmentation degree and the demographic characteristics), δ_0, δ_1, δ_2 are unknown parameter vectors, v_i is an unobserved time-invariant effect, and u_{it} is an i.i.d. error.

Following our considerations of both endogenous labor market access and previous empirical literature (Sumner, 1982; Benjamin, 1992; Skoufias, 1994; Wang et al., 2007), in the following we treat the wage as potentially endogenous. A Fixed Effects-Two Stage Least Square (FE-2SLS) model can control endogeneity, but when some households do not provide off-farm labor in a specific year, the off-farm wage cannot be observable and the FE-2SLS model suffers from sample selection bias due to the incidental truncation of the off-farm labor participation. In this case, a test for sample selection bias is indispensable (Wooldridge, 2002, 551-552).

Simultaneously considering sample selection and unobserved heterogeneity is methodologically challenging if households switch their selection status over time. In this case, the typical within estimators to sweep out fixed effects cannot be used, as the group of selected households changes its composition over time. There are two competing approaches in the literature describing how to circumvent this issue. The first is from Wooldridge (1995), who proposes estimating level equations in which the conditional expectations are parameterized by using Heckman-type corrections for each year in the panel, whereas fixed effects are controlled for by including time averages of the exogenous variables in the equation (following Mundlak 1978). The second approach goes back to Rochina-Barrachina (1999), and is based on matching selected households in first differences. In the following, we adopt Wooldridge's (1995) methodology because it does not require differencing and is more suitable for unbalanced datasets based on level estimations, (see Dustmann and Rochina-Barrachina, 2007, for discussion). The off-farm labor supply function and the wage function for off-farm wage can be expressed as follows:

(11) $$L^{o}_{it1} = \delta_0 + \delta_1 w_{it1} + \psi_1 x_{it} + \psi_2 \bar{x}_i + \ell_t \lambda(H_{it2}) + u_{it1},$$

where $\bar{x}_i$ is the means of independent variables except for off-farm wage, $\lambda(\cdot)$ are the inverse Mills ratios (IMR) calculated according to H_{it2}, which is a reduced index for the selection equation and determined by the probit model:

(12) $$s_{it} = 1[\varphi_{t2} x_{it2} + \upsilon_{i2} + \varepsilon_{it2} > 0], \qquad \varepsilon_{it2} \mid x_i \sim \text{Normal}(0,1)$$

where $\psi_1, \psi_2, \varphi_{t2}$ and ℓ_t are unknown parameter vectors, and ε_{it2} is an idiosyncratic error. To conserve the degrees of freedom (Wooldridge, 2002, 582), we adopt Mundlak's (1978) approach to estimate H_{it2}, and replace υ_{i2} with $\eta_2 + \xi_2 \bar{x}_{i2}$. Thus, the probit model becomes:

(13) $$s_{it} = 1[\eta_2 + \gamma_{t2} x_{it2} + \xi_2 \bar{x}_{i2} + \varepsilon_{it2} > 0], \qquad \varepsilon_{it2} \mid x_i \sim \text{Normal}(0,1)$$

where η_2, γ_{t2} and ξ_2 are unknown parameter vectors, x_{it2} contains all the exogenous variables, which are the exogenous variables in equation (11), x_i, and instrumental variables for w_{it1}, and $\bar{x}_{i2}$ is the vector of means of all the exogenous variables.

The log of pesticide price, distance of village to main concrete road (km), and average net income per capita in the village are chosen as instrumental variables for the off-farm wage. Higher average net income per capita in the village may contribute to an increase in off-farm wage, while higher pesticide price and longer distance of village to main concrete road may result in a lower off-farm wage. The amount of off-farm labor supply is changed correspondingly. Further, we test the quality of selected instrumental variables by using overidentification and underidentification tests, which can be found in the results section.

The off-farm labor supply could also be influenced by demographic characteristics of the households, the number of members in the household, the number of household members with an elementary education level, the number of members with a secondary school education level, and the number of members with a high school education level. In addition, the percentage of total arable land included in the village land market and the

log of average land per capita in the village are also controlled for in the off-farm labor supply function. The probit model in equation (14) is projected on all the exogenous variables including the number of plots, the instrumental variables and the control variables in the abovementioned off-farm labor supply function, as well as the means of all exogenous variables.

5 Data

The database used in this paper comes from the three Chinese provinces of Zhejiang, Hubei and Yunnan. The survey was conducted by the Rural Survey Team of the Research Centre for Rural Economy in the Ministry of Agriculture in China (RCRE). The empirical study is based on a panel data set covering 9 villages in Zhejiang, 15 villages in Hubei, and 5 villages in Yunnan, and contains annual data from 1995 to 2002. Zhejiang is one of the most developed provinces, where land, labor, insurance and credit markets are more developed compared to its counterparts; Hubei is one of the most important agricultural provinces; Yunnan is a less developed province in the west of China.

The description of the dataset is shown in Table 1. The average farm size is 4.85 mu, with an average of 6.66 plots. The overall average labor input is 238 person days. The average off-farm labor input is 326 person days. Each household contains an average of 4 persons, and among them one person graduated from elementary school, and one person graduated from secondary school; only one of every six households has a high school graduate.

6 Results

6.1 The effect of land fragmentation on agricultural labor productivity

The regression results for the translog production function for both the FE model and the time-demeaned OLS are shown in Table 2. All coefficients of the three inputs of labor, land and capital are positive. The inputs represent the production elasticities at geometric sample means and are generally in a plausible order of magnitude. Scale elasticity, given as the sum of the partial production elasticities of the three inputs for time-demeaned OLS in the last two columns in Table 2, is 0.87, which is consistent with the findings of Wan and Cheng (2001). Hence, the mean farm operates at decreasing returns to scale, which is theoretically consistent. Labor elasticity is 0.26, and capital elasticity is 0.25, both of which are similar to the results estimated by Lin (1992), while the land elasticity is 0.36, which is lower in our case.

Land fragmentation reduces total farm output, but the only channel through which this happens is via reducing labor productivity. Land fragmentation decreases the MPL ($\beta_5 < 0$). At sample means, a decrease in the number of plots by 10% raises agricultural labor productivity by approximately 1.5%. The increased output from an additional labor input cannot compensate for the loss due to land fragmentation. Therefore, land fragmentation lowers MPL. This conclusion is further confirmed by a post-estimation of the model. We calculate the MPL according to the estimate result in Table 2 and map it against number of plots in each year. Figure 3 shows that the MPL decreases with the increase of the number of plots in all years. The reduction of capital input resulting from

land fragmentation is not significant, which may be due to less machinery usage in these three provinces.

Earlier we noted the potential endogeneity problem in labor use. Farmers who participate more in off-farm work are also likely to be the ones who have a higher MPL, for example because they are younger or better-educated (Huang et al., 2009). The omitted farmer's ability is likely to be positively correlated with the MPL, so that the estimated coefficient on labor use is biased upwards and represents an upper bound to the real coefficient. Another concern in our production function is the inability to include the application of organic manure. Qiao et al. (2011) found that the application of organic manure increased in poor areas due to more backyard livestock, and declined in rich areas. Poor areas are often located in mountainous regions with a higher degree of land fragmentation. In other words, highly fragmented farms appear to be more productive in the data because they apply more manure. This means the omitted manure application variable may falsely bias upwards the marginal product of the number of plots. Both of these omitted variables lead the coefficient of land fragmentation on agricultural labor productivity β_5 to be an overestimation of the true effect. The negative effect found in our study will thus be even lower if other sources of endogeneity were controlled for.

An important finding presented in this section is that land consolidation will make on-farm work more productive. As a consequence, land consolidation will reduce the off-farm labor supply of farm households, whereas further fragmentation will increase it. We turn now to a direct examination of this issue in the next section.

6.2 The effect of land fragmentation on off-farm labor supply

To directly analyze the effects of land fragmentation on off-farm labor supply,
we first estimate equation (10) using the conventional FE-2SLS model (Table 3). An increase in the off-farm wage raises off-farm labor supply, whereas the land fragmentation effect is close to zero; both coefficients are not significantly different from zero. The household size and all education levels give rise to the off-farm labor supply, while the land endowment dampens it. This result is robust to endogeneity, time-invariant heterogeneity and the clustering characteristics of samples, but is subject to sample selection bias.

To control the sample selection bias, we estimated equation (11) with pooled 2SLS following Wooldridge's (1995) model, and the results are reported in the last two columns in Table 3. The tests for the panel data sample selection bias and the fixed effects were obtained by employing joint Wald tests. The null hypothesis is ($H_O : \ell_1 = \ell_2 ..... = \ell_8 = 0$), i.e. there is no sample selection bias. The Wald test statistical results reveal that the null hypothesis is rejected at the 1% significance level (χ_8^2 =36.79). Therefore, controlling sample selection bias in the panel data is required when estimating off-farm labor supply. The null hypothesis for fixed effects test is ($H_O : \psi_1 = \psi_2 ..... = \psi_7 = 0$), i.e. a random effects model should be applied. This null hypothesis is also rejected by the Wald test at the 1% significance level (χ_7^2 =50.78), suggesting a fixed effects model. In this way, the model is robust to sample selection bias, and allows a correlation between the unobserved heterogeneity and the independent variables. According to Wooldridge (1995), the standard errors should be corrected to

heteroscedasticity and serial correlation. However, we cannot control serial correlation and obtain cluster robust standard errors at the same time. In this paper, the issue of clustering samples is more important than serial correlation, since there are 100 to 1,000 observations in each village, while there are only 8 years in the time series. Thus, the cluster of robust standard errors is given priority to be controlled; the standard errors are robust to heteroscedasticity and clustering on the village level.

Hence, the estimated coefficients suggest that land fragmentation tends to have positive impacts on the off-farm labor supply, which is consistent with our findings in the previous section. However, the statistical significance of these coefficients could not be established. A natural explanation for this finding is the potential imperfections present in Chinese rural labor markets as listed in section 2.3.

The other results in Table 3 reveal that an increase in the off-farm wage significantly leads to an increase of the off-farm labor supply, which is consistent with previous studies indicating that the off-farm wage has a positive relationship with off-farm labor supply (Sumner, 1982; Wang et al., 2007). Households with greater land endowments are more involved in agricultural production, thus leading to a reduction of off-farm work. Households with more members have stronger intentions to participate in off-farm work than other households, but the number of members in the household has no significant impact on off-farm labor supply after controlling for sample selection bias. Households with better education have more opportunities to supply more off-farm labor than other households, which supports findings by other authors indicating that increasing years of schooling contributes to the participation of off-farm work (de Brauw et al., 2002; Uchida et al., 2009).

The null hypotheses cannot be rejected in overidentification tests, and are rejected in underidentification tests in both FE-2SLS and Wooldridge's models, indicating that the instrumental variables are valid in both models, as reported in Table 3. The first stage results for the instrumented off-farm wage are reported in Table 4. The distance of village to main concrete road reduces the off-farm wage, and the average net income per capita in the village increases off-farm wage, both of which exhibit significant and plausible signs.

The findings of this section lend further support to the idea that land consolidation may lead to reductions in the off-farm labor supply in rural China, but does not exhibit a significant effect due to constrained labor market. A likely explanation for this finding is that part-time farmers are the ones heavily constrained from expanding their labor market participation. If this is true, their labor market behavior cannot react to changing fragmentation degrees, and an ultimate answer to the fragmentation effects on labor markets cannot be given.

7 Conclusions

This paper aims to clarify the relationship between land fragmentation and off-farm labor supply among Chinese farm households. Building on household-level panel data from three structurally different provinces, our results support the conventional wisdom that, holding other inputs constant, more fragmented farms are less productive. However, by employing a flexible production function, we extend the literature by showing that

this productivity loss occurs because land fragmentation reduces labor productivity. This finding establishes a direct link to the issue of off-farm labor supply, as it means that more consolidated land makes farmwork more attractive and thus reduces off-farm labor supply. This result is in contrast to suggestions by Tan et al. (2008), who argue that farmers with more fragmented land use more labor to compensate for the negative effects of fragmentation. According to our findings, land fragmentation makes labor less productive, so that a rational response will be to use less of it on-farm, and rather switch to off-farm income-generating activities. By using Wooldridge's (1995) panel data sample selection model, we directly estimate the effect of land fragmentation on off-farm labor supply. However, this effect cannot be reflected in observed labor time allocations due to labor market imperfections.

The land market policy of the Chinese government has recently displayed a tendency towards reducing administrative land reallocations at the local level, and granting more permission to participate on local land rental markets. The land tenure contract was expanded from 30 years in 2002 (Rural Land Contract Law), to an unspecified "long term" in 2008 (3rd plenary meeting of the 17th Party Congress), and land reallocation is only allowed when two-thirds of the villagers' representatives approve it (Wang et al., 2011). This policy is intended to encourage unproductive farmers to transfer their farmland to other farmers, and to stimulate voluntary land consolidation through land markets, thereby increasing agricultural productivity. As it is based on data available before 2002, our analysis could not include the Rural Land Contract Law. Nevertheless, against this policy background, our findings have clear implications. If more liberal land market policies and hardened property rights will allow more consolidated farmland in the future, this will not trigger a flood of former farmers leaving rural areas in search for alternative incomes. Since it makes farm work more productive, it will rather provide an incentive to continue farming and increase agricultural productivity.

This conclusion comes with one important caveat. The analysis in this paper examined a sample of continuously existing farms, operated either full-time or part-time. Farm exits were not considered. Improved opportunities to consolidate farmland due to better functioning land markets may convince some of the least productive farmers to give up farming altogether, and earn their living fully from nonfarm sources. This process may well increase the number of urban job seekers, and may lead to increasing specialization and differentiation within the pool of Chinese rural households.

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Table 1: Data description

Variable	*Mean*	*Std. Dev.*
For production function		
Value of Output (1995 yuan)	1,026.87	872.15
Labor (person days)	237.61	158.34
Capital (1995 yuan)	576.82	417.67
Land (mu)	4.85	3.80
Number of plots	6.66	4.92
Number of observations	12,104	
For off-farm labor supply function		
Off-farm labor input (per person days)	325.95	244.18
Off-farm wage (yuan/day)	30.05	47.02
Pesticide price (yuan/kilogram)	15.31	9.48
Distance of village to main concrete road (km)	1.61	3.31
Percentage of total arable land participating in village land market	0.08	0.14
Number of plots	5.91	4.26
Number of members in the household	4.19	1.38
Average land per capita in the village (mu)	1.08	0.80
Number of members having elementary education level in the household	1.09	0.90
Number of members having secondary school level in the household	1.03	0.94
Number of members having high school level in the household	0.17	0.45
Average net income per capita in the village (yuan)	2,781.23	2,090.97
Number of observations	7,302	

Table 2: Translog production function with time-demeaned OLS

	FE model		*Time-demeaned OLS*	
Variable	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*
Labor	0.16**	0.06	0.26***	0.08
Capital	0.3***	0.07	0.25***	0.07
Land	0.37***	0.04	0.36***	0.05
Plots	-0.01	0.04	0.08	0.05
Plots*labor	-0.05	0.05	-0.15**	0.07
Plots*land	0.07	0.06	0.13	0.14
Land*capital	0.04	0.03	0.03	0.05
Capital*labor	-0.02	0.03	-0.1***	0.03
Plots*capital	-0.03	0.04	-0.08	0.07
Labor*land	0.05	0.07	0.22**	0.11
Labor^2	-0.11***	0.03	-0.03	0.05
Capital^2	0.04**	0.02	0.04**	0.02
Land^2	-0.01	0.04	-0.05	0.08
Plots^2	-0.06	0.04	0.07	0.06
Constant	0.36	0.23	-	-
Year dummies	Yes		Yes	
Number of obs.	12,104		12,104	
Cluster robust standard errors	Yes		Yes	
Number of clusters	29		29	

Note: all metric variables demeaned and in logs. *** indicates a 1% significance level, ** indicates a 5% significance level, and * indicates a 10% significance level.

Table 3: Estimation results of off-farm labor supply

	FE-2SLS without sample selection		*Wooldridge (1995) sample selection model*	
Variables	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*
Log of off-farm wage	0.18	0.16	0.64***	0.24
Log of plots	0.02	0.07	0.13	0.09
Percentage of total arable land participating in the village land market	0.07	0.16	-0.01	0.26
Number of members in the household	0.04**	0.02	0.02	0.02
Log of average land per capita in the village	-0.09*	0.05	-0.14**	0.07
Number of members having elementary education level in the household	0.10***	0.03	0.11***	0.04
Number of members having secondary school level in the household	0.24***	0.04	0.23***	0.04
Number of members having high school level in the household	0.25***	0.04	0.21***	0.05
F	F(8, 28) = 17.44		F(8, 28) = 8.24	
Overidentification test (p-value)	0.73		0.18	
Underidentification test (p-value)	0.02		0.01	
Number of observations	7,302		7,302	
Corrected standard errors	Yes		Yes	
Number of clusters	29		29	
Sample selection	No		Yes	
Fixed effects controlled by	Differencing out group average		Mundlak's approach	

Note: *** indicates a 1% significance level, ** indicates a 5% significance level, and * indicates a 10% significance level. The dependent variable is the log of the off-farm labor supply. Sample selection bias test for Wooldridge's method: χ_8^2 =36.79(0.01). Fixed effects test for Wooldridge's method: χ_7^2 =50.78(0.00).

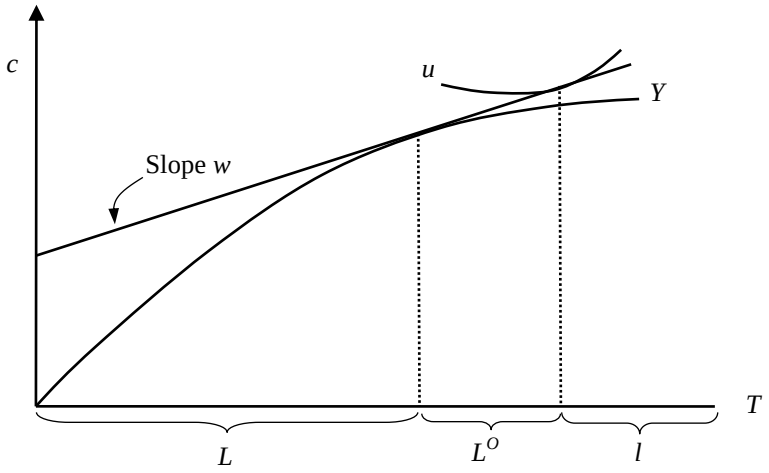
Table 4: First-stage regression results for off-farm wage

	FE-2SLS without sample selection		*Wooldridge (1995) sample selection model*	
Variables	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*
Log of plots	-0.08**	0.04	-0.06	0.03
Percentage of total arable land participating in the village land market	0.14	0.21	0.21	0.19
Number of members in the household	3.36E-3	0.01	0.02	0.01
Log of average land per capita in the village	-0.02	0.03	0.01	0.04
Number of members having elementary education level in the household	0.01	0.02	-0.02	0.02
Number of members having secondary school level in the household	-0.01	0.03	-0.05	0.03
Number of members having high school level in the household	-0.02	0.03	-0.03	0.04
Log of pesticide price	-0.02	0.02	-0.02	0.03
Distance of village to main concrete road (km)	-0.02***	3.2E-3	-0.02***	0.01
Average net income per capita in the village	9.05E-5***	2.93E-05	7.5E-5***	2.8E-5
F (P-value)	F(8,28) = 5.96 (0.00)		F(13,28) = 9.71 (0.00)	
Partial R^2 of excluded instruments	0.02		0.06	
Number of observations	7,302		7,302	
Corrected standard errors	Yes		Yes	
Number of clusters	29		29	

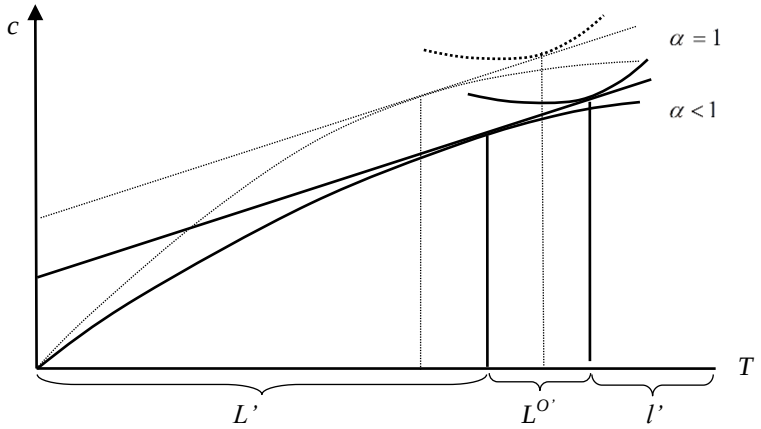
Note: *** indicates a 1% significance level, ** indicates a 5% significance level, and * indicates a 10% significance level. The means of excluded instrumental variables for off-farm wage are included in the estimation but not presented in the table.

Figure 1: Land fragmentation in the separable agricultural household model

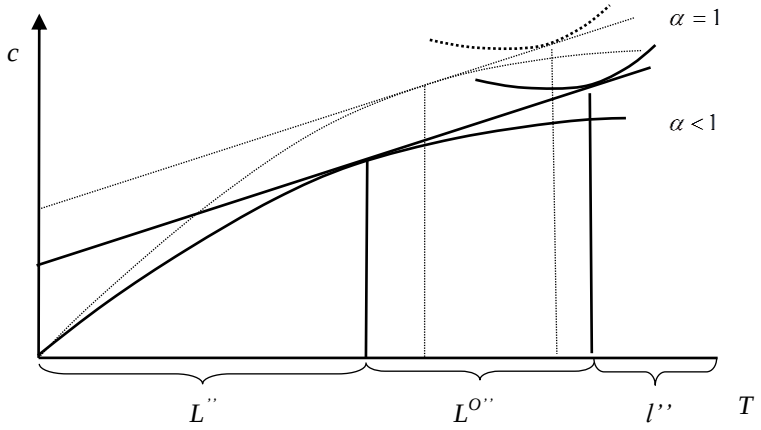
(a) separable household model



(b) land consolidation has positive effects on off-farm labor supply: $\partial L^O / \partial \alpha > 0$

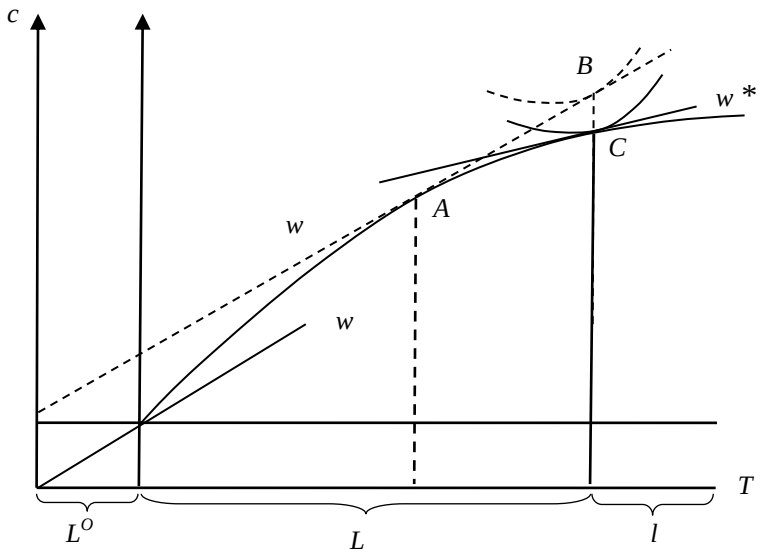


(c) land consolidation has negative effects on off-farm labor supply: $\partial L^O / \partial \alpha < 0$



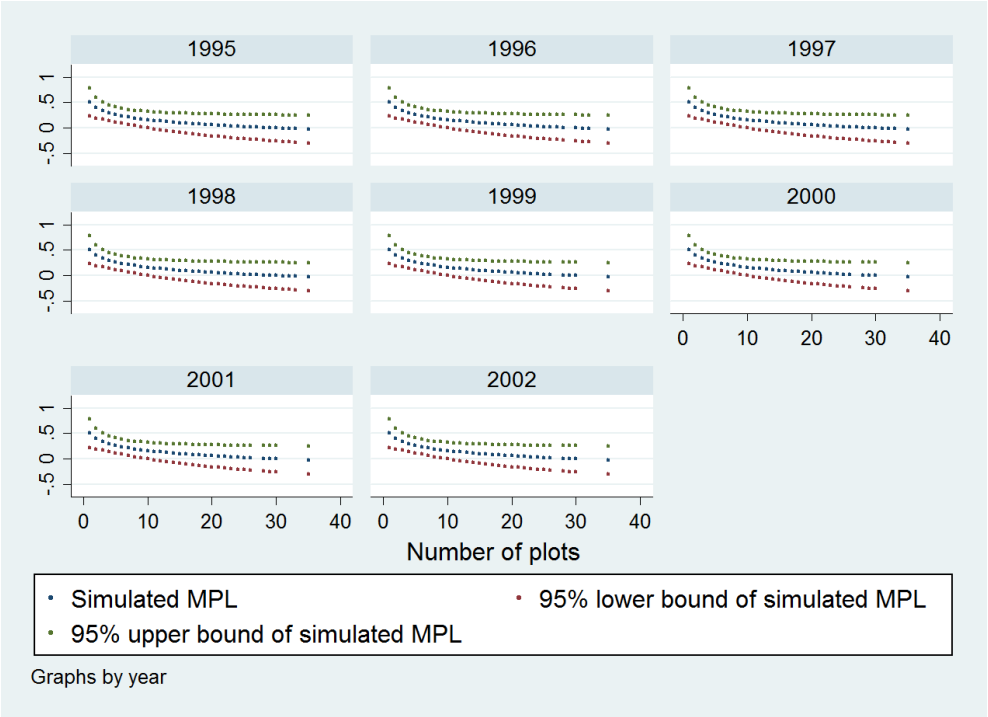
Source: Author's depiction.

Figure 2: Off-farm labor supply in a non-separable agricultural household model



Source: Adapted from Benjamin (1992).

Figure 3: The effect of land fragmentation on MPL



Source: Authors' calculations.

Note: This figure is provided based on a referee's suggestion.