Scale Effects, Technical Efficiency and Land Lease in China

Xiaobing Wang

Center for Chinese Agricultural Policy
Institute of Geographical Science and Natural Resource Research
Chinese Academy of Sciences
Email: xbwang.ccap@igsnrr.ac.cn

Xiaohua Yu*

Junior Professor
Courant Research Centre "Poverty, Equity and Growth"
Georg-August-Universität Göttingen
Platz der Göttinger Sieben 3, 37073 Göttingen, Germany
Phone: +49-551-39 14066
Fax: +49-551-39 14059
Email: xyu@gwdg.de

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*Corresponding Author

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Abstract:

Using a panel dataset from Zhejiang province in China over the period 1995-2002, we propose a two-step estimation procedure to investigate the links between land lease activity and production efficiency. We find that the output elasticity with respect to land, the scale effect and the technical efficiency are higher for farmers involved in land-lease activities. In addition, technical efficiency and land-lease activity are endogenous, and farmers with higher technical efficiency are more likely to lease more land and adopt advanced technologies to achieve higher profits, which in turn alters the technical efficiency.

Key Word:

Land Lease, Land Use Rights, Technical Efficiency, Scale Effect.

Jel Code:

Q15, P23, D50.

1. Introduction

The success of Chinese agricultural development has been attributed to a series of radical land reforms aiming at egalitarian principles (Lin, 1992). At the core of the reforms lied the coexistence of land ownership, which remained collective at the village level, and land use rights, which were equally distributed among individual farmers. Under this strict separation of land title and distribution, land trade or more generally the transfer of a land title, as a potential instrument to improve efficiency and productivity growth, is legally prohibited. This prohibition of land title transfer is of vital importance for Chinese policy makers, as land is traditionally regarded to be the most fundamental way to secure the lives and livelihoods of millions of Chinese smallholder engaged in agricultural production (Brandt et al., 2002). The regime of land use rights designed by the Chinese government and the evolution of the land rental market provide a unique opportunity to explore the causality between transfers of land use rights taking the form of land-lease activities and changes in production efficiency.

The current institutions regarding the transfer of land use rights have an important implication for improvement of land productivity and economic efficiency to ensure food security and satisfy increasing food demand induced by fast economic growth (Huang and Rozelle, 1995; Jacoby et al., 2002). The incidence of land-lease activity, which is an indicator of the functioning of land markets, has obvious consequences in changing production technology and other input use, which ultimately affects farmers' profits. By allowing farmers to achieve their desired levels of land input, or in other words to employ the profit-maximizing amount of land in production, the transfer of land use rights permits a more efficient allocation of resources among farmers. Empirical studies have well documented that the functioning of land lease markets at the farmer or village level increases technical efficiency (Bruemmer et al., 2006; Zhang et al., 2011). The transfer of land use rights is an important instrument to achieve an efficient allocation of resources and potentially also to enhance production scale efficiency (Fleisher and Liu, 1992; Wan and Cheng, 2001; Silor et al., 2009).

However, there is a problem regarding the analysis of causalities between production efficiency and land lease activity. When analyzing farm operation decisions about transfers of land use rights, it is natural to consider on the one hand whether less efficient farmers are indeed more likely to lease more land in order to improve the scale effect, especially under the condition of fragmented agricultural production, and catch up with more efficient farmers in terms of income. On the other hand, it might be the case that farmers with the capacity of organizing their production closer to the production frontier tend to lease more land. Expanded farm size might in this case induce the adoption of new labor-saving technologies, such as medium- or large-sized machinery (Hayami and Ruttan, 1985).

In particular, the disagreement regarding the relationship between land lease activity and technical efficiency makes it necessary to recognize that land lease decisions might be endogenous with respect to production efficiency and vice versa. The adoption of new technologies induced by an increase in scale will, of course, change the technical efficiency, which is one of the important components of productivity growth. The analysis of determinants of technical efficiency without consideration of the endogeneity problem is inadequate for modeling Chinese agricultural production. When the feedback effects of land lease choice on production efficiency are not taken into account, the traditional methods, that are estimating the land lease choices by binary models or the demand for leased land by Tobit models, are not satisfactory.

In this study, we aim at gaining a deeper understanding of the relationship between land lease activity, scale and technical efficiency of agricultural production and empirically investigate this relationship using panel household and village survey data collected in Zhejiang province by the Chinese Ministry of Agriculture in the time period from 1995 through 2002. Our theoretical framework provides a formal conceptual analysis of the endogeneity by allowing land lease activity and technical efficiency to affect each other and by identifying the equilibrium between land lease activity and technical efficiency. Our empirical model considers the different technologies determined by the land lease choices and tests the systematic differences between them. Consequently, we employ a structural equation system to estimate the technical efficiency and land lease decisions simultaneously.

To meet these objectives, the rest of the paper will be organized as follows. In section two, we lay out economic models and identify the equilibria. The next section presents the dataset and describes the incidence of land lease activity. Section four discusses the endogeneity between the incidence of land lease activity and technical efficiency. The final section concludes.

2. Models

2.1 Modeling Production

Even though production efficiency comprises technical efficiency, allocative efficiency and scale efficiency in the current literature (Kumbhakar and Lovell, 2003), we will mainly look into the technical efficiency and scale effects because the inputs market is not perfect and we do not have the information of input prices in our dataset. In order to empirically examine the links between scale effects, technical efficiency and land lease incidence, we first model farmers' production, which is specified in a Translog form. Given the panel structure of the data, the model used in this study is the Panel Stochastic Frontier Model (PSFM) with time-varying technical efficiency proposed by Battese and Coelli (1992). The physical inputs include cultivated land area comprising both owned land and leased land subject to the incidence of land lease activity, labor input, capital and expense on intermediate inputs including fertilizer, pesticides and seeds. The production function is specified as

$$\ln Y_{it} = \beta_0 + \sum_j \beta_j \ln X_{jit} + \sum_j \sum_{n \geq j} \gamma_{jn} \ln X_{jit} \ln X_{nit} + \lambda t + \alpha_i + v_{it} - u_{it} \quad (1)$$

where Y_{it} is total agricultural revenue for farmer i at time t; X_{jit} is the physical input j; β_j and γ_{jn} are related coefficients. A time trend is added to capture the technical progress, and

α_i captures the fixed-effects of farmer i. Furthermore, v_{it} is a random term with a normal distribution $v_{it} \sim N(0, \sigma_v^2)$ and u_{it} is a non-negative term capturing the technical efficiency. Following Battese and Coelli (1992), we assume technical efficiency changes over time for each farmer i,

$$u_{it} = \exp\{-\eta(t - T_i)\}u_i \tag{2}$$

where T_i is the last observed period for farmer i; η is a term denoting the decay rate of technical efficiency; and u_i follows a truncated normal distribution with variance σ_v^2. Then the technical efficiency can be expressed as $E_{it} = \exp(-u_{it})$.

2.2 Output Elasticity and Scale effect

Given the production function in Equation (1), output elasticity with respect to input j is

$$e_j = \frac{d \ln Y_{it}}{d \ln X_{jit}}$$

$$= \beta_j + 2\gamma_{jj} \ln X_{jit} + \sum_{n \neq j} \gamma_{jn} \ln X_{nit} \quad . \tag{3}$$

Following Kim (1992), the scale effect can be written as

$$\theta_{it} = \sum_j \frac{d \ln Y_{it}}{d \ln X_{jit}}$$

$$= \sum_j \beta_j + \sum_j \sum_{n \neq j} \gamma_{jn} \ln X_{nit} + 2 \sum_j \gamma_{jj} \ln X_{jit} \quad . \tag{4}$$

2.3 Technical Efficiency and Land Lease

Even though Kumbhakar et al. (2008) proposed a one-step method to jointly estimate the production function and organic choice function to correct the possible endogeneity of organic choice for dairy farming, the method cannot be used here. The reason for this is that it would imply that technological efficiencies are different but the adopted technologies between the two types of farmers are identical. In fact, this is not realistic. Not only technical efficiency, but also adopted technologies could be systematically different between organic and conventional farmers, and similarly between lease farmers and non-lease farmers in this study.

We use the traditional two-step method: Step 1: Estimate Equation (1) separately for lease farmers and non-lease farmers. Step 2: Estimate the lease function by instrumental variable regressions. The first step estimates de facto technical efficiencies for each type of farmers. If the technologies are systematically different for the two types of farmers, the sample selection problem pointed out by Kumbhakar et al. (2008) does not exist any longer as they are generated from different processes. After the estimated technical efficiency for each farmer in hand by Equation (2), we will examine the link between lease decision and technical efficiency. In order to address the possible endogeneity, we specify a structural equation system comprising a land lease function and a technical efficiency function.

First, it is reasonable that farmers with high efficiency are more likely to lease more land to employ the profit-maximizing amount of land in production under the institutional restriction of egalitarian rules of land allocation among farmers. However, only a few farmers lease land, so that the land lease function is specified as a Tobit model,

$$L_{it}^{\ *} = \delta E_{it} + Z_{it} b + \varepsilon_{it} \qquad (5.a)$$

$$L_{it} = \begin{cases} L_{it}^{\ *} & if \quad L_{it}^{\ *} > 0; \\ 0 & if \quad L_{it}^{\ *} \le 0. \end{cases}$$

where $L_{it}^{\ *}$ is a latent variable. If $L_{it}^{\ *} > 0$, the leased land area L_{it} can be observed; otherwise, there is no lease activity; δ is the coefficient for technical efficiency. Z_{it} is a vector of exogenous variables determining land lease activity, such as off-farm employment opportunities, and b is a vector of the corresponding coefficients. ε_{it} is a random term with a normal distribution $\varepsilon_{it} \sim N(0, \sigma_{\varepsilon}^2)$ [1].

Furthermore, there is a feedback impact of the size of the leased land area on technical efficiency, which is assumed to be nonlinear. Usually, in economic theory, a relatively small amount of leased land can incentivize farmers to improve technical efficiency as the technology is not changed. However, a large amount of land may rapidly increase the costs of management and supervision beyond the farmers' ability, which makes production less efficient. In particular, large farms often introduce advanced technologies, such as advanced machineries or hybrid seeds, requiring advanced human capital and complicated skills, which are limited for many farmers, thereby possibly reducing efficiency (Xu and Jeffery, 1999). Thus, we hypothesize that technical efficiency follows a quadratic function of the size of the leased land area, implying that as the size of the leased land area increases, the technical efficiency first increases and then decreases. The technical efficiency function can be specified as

$$E_{it} = \rho_1 L_{it} + \rho_2 L_{it}^{\ 2} + \tilde{Z}_{it} \tilde{b} + \tilde{\alpha}_i + \tilde{\varepsilon}_{it} \qquad (5.b)$$

where ρ_1 as well as ρ_2 are parameters and $\rho_2 < 0$; $\tilde{Z}_{it}$ is a vector of exogenous variables determining farmers' technical efficiency as in other studies, such as farmers' human capital and labor participation rate; and $\tilde{b}$ is a vector of the corresponding coefficients. $\tilde{\alpha}_i$ captures the fixed effects and $\tilde{\varepsilon}_{it}$ is a random term with a normal distribution $\tilde{\varepsilon}_{it} \sim N(0, \tilde{\sigma}_{\tilde{\varepsilon}}^{2})$.

The relationship between land lease activity and technical efficiency in Equation (5.a) and (5.b) is shown in Figure 1, which indicates that there are two equilibria: A and B. In particular, A is an unstable equilibrium whereas B is a stable one. After solving the system consisting of Equations (5.a) and (5.b), we find that the stable equilibrium is given by

$$E^{'} = \frac{-[\rho_1\delta + 2\rho_2(Z_{it}b)\delta - 1] - \sqrt{[\rho_1\delta + 2\rho_2(Z_{it}b)\delta - 1]^2 - 4\rho_2\delta^2[\tilde{Z}_{it}\tilde{b} + \tilde{\alpha}_i + \rho_1(Z_{it}b) + \rho_2(Z_{it}b)^2]}}{2\rho_2\delta^2} \quad (6.a)$$

and

$$L^{'} = (Z_{it}b) + \frac{-[\rho_1\delta + 2\rho_2(Z_{it}b)\delta - 1] - \sqrt{[\rho_1\delta + 2\rho_2(Z_{it}b)\delta - 1]^2 - 4\rho_2\delta^2[\tilde{Z}_{it}\tilde{b} + \tilde{\alpha}_i + \rho_1(Z_{it}b) + \rho_2(Z_{it}b)^2]}}{2\rho_2\delta} \quad (6.b)$$

In the rest of this paper we will use a panel dataset from China to empirically examine the determinants of land lease incidents and their impacts on efficiency.

[1] Due to the Incidental Parameter Problem, the fixed-effects model for the Tobit model (3.a) cannot be applied.

3. Data

The data used in this study are drawn from the fixed-point survey data series in Zhejiang Province in China, conducted annually by rural survey teams from the Chinese Ministry of Agriculture. After cleaning the data, we establish an unbalanced panel with 2,320 observations from 1995 to 2002. Table A1 presents the definitions of the variables used in this study.

It indicates that both the incidents of lease activities and the average size of the leased land area have substantially increased over the course of our observation period. Particularly, the percentage of lease farmers increased from 14.7% in 1995 to 27.1% in 2002, and about one-fifth of farmers had taken part in land lease activities. The average size of the leased land area has more than doubled from 1.28 mu in 1995 to 2.61 mu in 2002, implying an improved functioning of the land lease market. The increase in land lease activities provides evidence for the development of land lease markets and the emerging specialization of agricultural production in China (Kung, 2002). In addition, it also motivates the studies by raising the questions: who experienced the specialization and benefitted from it, and which farmers are more efficient in organizing agricultural production? These questions will be answered in the remaining sections of this study.

4. Estimation and Discussion

4.1 Estimation of the production function

In order to scrutinize the link between farmers' lease behavior, scale effects and technical efficiency, we first need to obtain the technical efficiency by estimating the PSFM–Equation (1). The inputs include land, labor, capital and intermediate inputs. A time trend variable is also included to capture the technical innovations.

The results are shown in Table 1, which includes three estimation models: full sample model, Non-Lease Sample Model and Lease sample model because we speculate that there may exist structural differences both for technical efficiency and for technologies between non-lease farmers and lease farmers.

Compared with the results of the fixed-effects models, the PSFMs perform better because more variables are statistically significant. Regarding the diagnosis of the structural differences between the non-lease farmers and lease farmers, the result of a likelihood ratio test rejects the null hypothesis that there is no significant difference between them, which also authenticates the legitimation of the two-step estimation. Thus, we accept the alternative hypothesis that there are structural differences between the lease- and non-lease farmers, which might be caused by differences in technology and/or technical efficiency. The following discussion will be based on the results from the separated estimations in the PSFMs.

In order to avoid numerical difficulties in the maximum likelihood estimations, and to facilitate the interpretation of the parameter estimates, the output variable and the four input variables are represented by their respective sample means. Hence, based on Equation (3) we can calculate the output elasticities with respect to each input as elasticities at the point of normalization, i.e. at the sample mean. The results are quite consistent between non-lease farmers and lease farmers. With a value above 0.30 for both non-lease and lease farmers in Zhejiang Province, the output elasticity with respect to intermediate inputs is the highest in all inputs. Other important inputs are labor and land. Interestingly, the output elasticity with respect to capital is slightly negative, indicating that capital in Zhejiang province is slightly overused. Given the fact that Zhejiang province is one of the richest provinces in China, it is plausible that capital for agricultural production could be in abundant supply .

4.2 Scale effects

Using equation (4), we can calculate the scale effects for both non-lease and lease farmers at the mean of the input variables. The results show that the return to scale is fluctuating over the observation period both for non-lease and for lease farmers. However, as expected, the returns to scale for lease farmers are in general higher than those for non-lease farmers over this period except for the year 2001.

Furthermore, a t-test finds that the mean return to scale for lease farmers (0.854) is significantly higher than that for non-lease farmers (0.830). The level of statistical significance is 1%. This implies that farmers with leased land do benefit from scale effects, which is consistent with the reality that agricultural production is still conducted on small-sized and fragmented plots of farm land. Once scale economy may be present, it could transmit into improvement of productivity growth.

4.3 Technical efficiency

Our results indicate that the technical efficiencies of both non-lease and lease farmers decreased over the observed period. This is consistent with the assumption of the econometric model of Battese and Coelli (1992). Comparing non-lease with lease farmers, we find that the technical efficiency of lease farmers is in general much higher than that of non-lease farmers. The mean technical efficiency of lease farmers is 0.829 over the observed period, whereas the corresponding efficiency of non-lease farmers is 0.518. A t-test finds that the difference is significant at the 1% level.

Furthermore, by comparing these results with the previous literature (Bruemmer et al., 2006), we find that the technical efficiency of lease farmers is in accordance with recent findings. The technical efficiency of non-lease farmers however is significantly lower. This could be explained by the facts that lease farmers are specialized in agricultural production and that agriculture represents their main source of income. Hence, they have a higher technical efficiency. A large proportion of the non-lease farmers in Zhejiang province only regard agriculture as a part-time job and most of their income is from off-farm employment. This in turn suggests that they do not have incentives to improve their technical efficiency.

The obtained technical efficiencies allow us to estimate the simultaneous equations: lease behavior function (5.a) and technical efficiency function (5.b).

4.4 Lease Behavior

We first take a look at the lease behavior function (5.a), which is a Tobit model with technical efficiency as an endogenous variable. Smith and Blundell (1986) and Newey (1987) proposed a two-step method to estimate Equation (5.a), but their estimators are not as efficient as the maximum likelihood estimators, which will be used here. A comprehensive review can be found in Wooldridge (2002, p.532).

The functioning of land lease market under the constraints of imperfect labor markets has been well explored in the existing literature (Yao, 2000 and 2004; Kung, 2002; Vranken and Swinnen, 2006). The conclusion, which has been drawn, is that the determinants of participation in land lease market are affected by the household heterogeneity, including the age and educational attainment of the household head, and the allocation of working time between on- and off-farm jobs. Farmers' behavior with regard to land lease is also affected by the land endowment of their households in terms of land per capita and quality of land. Leasing land from the owners of adjacent plots in order to expand the cultivated area is a potential solution to the land fragmentation that resulted from the current land allocation system in rural China (Wan and Cheng, 2001). Furthermore, access to the land lease market could also be influenced by village characteristics like the development of labor markets, the location of the village or the population density (Wang et al., 2007). According to these conceptual notes, the factors which determine lease behavior, including household, farm and village characteristics, are introduced in the empirical estimation.

The instrument used for technical efficiency is the cluster technical efficiency, which is measured as the average technical efficiency of other farmers in a given village and year. It can be obtained from the PSFM and is believed to be correlated with technical efficiency but not with the error term of the equation. This approach allows us to evaluate whether and to what extent technical efficiency influences the land lease decision. The estimation results are reported in Table 2.

A likelihood ratio test rejected the null hypothesis that the technical efficiency is exogenous at the 1% level and thus accepted the alternative hypothesis of endogeneity, even though the estimation results of the two models are quite consistent. The following discussion will be based on the results of the IV estimation.

The coefficient estimate for technical efficiency is 15.47 and statistically significant at the 1% level. As the changes in technical efficiency are usually very small, the marginal impact of changes in technical efficiency on land lease activity is also small. Nevertheless, it is statistically significant, which implies that farmers with higher technical efficiency are more likely to lease more land and to specialize in agricultural production.

4.5 Determinants of Technical Efficiency

Here we start to analyze the determinants of technical efficiency by estimating Equation (5.b). The endogenous variables are lease area and squared lease area. Similar to other recent studies on technical efficiency (Zhang et al., 2011), the exogenous variables include household size, land size per parcel, average household education, education and age of the household head, capital, allocation of capital, allocation of agricultural land, land rent, and own land size.

The nonlinearity of the endogenous variable renders the estimation of Equation (5.b) somewhat difficult. Following the method described by Wooldridge (2002, p.233), we take the second-order term of the lease area as a new endogenous variable and use the variables of household labor share, off farm wage, shadow rent, shadow wage, logarithm of levies, as well as the second-order and interaction terms of these variables as instruments for the endogenous variables. The results of several models including pooled and fixed-effects estimation are reported in Table 3.

F-tests reject the pooled regressions and favor the fixed-effects models. Furthermore, Hausman tests reject the null hypothesis of exogeneity and thus support the alternative hypothesis of endogeneity. For comparison, we also estimate a restricted model only including the first-order term of lease area, but a t-test indicates that there is a non-linear relationship between lease area and technical efficiency. Consequently, the following discussion is based on the fixed-effects instrumental variable regression for the non-linear model.

First of all, the coefficients for the first-order and second-order terms of lease area are 0.0393 and –0.0007, respectively, and both are statistically significant at the 1% level. This indicates that there is an inverted-U shape relationship between the area of leased land and technical efficiency. More precisely, when the lease area increases technical efficiency first increases and then decreases, which is consistent with our theoretical framework. If we were to ignore the feedback effect of technical efficiency on land lease activity, farmers could reach the maximum technical efficiency at a leased land area of 27.1 mu, which is the benchmark of the non-small farm holders as defined by the World Bank (2003). Even though this scale is still low in the international standard, but being reasonable enough to enhance the economy of scale without changing the current land tenure system in rural China.

Moreover, the results also indicate that only own land size and allocation of agricultural land are marginally significant. Specifically, own land size is negatively correlated with technical efficiency, which could be explained by the fact that farmers with more own land are often characterized by a lower technical efficiency. Allocation of agricultural land has a positive impact on technical efficiency, indicating that farmers who allocate more land to grain production have higher technical efficiency, which reflects the fact that the production process of cash crops is usually more complicated than that of grain crops.

4.6 Equilibrium of Lease Behavior and Technical Efficiency

Our theoretical framework indicates that there is a stable equilibrium in the long run, which is given by Equations (6.a) and (6.b). Taking the mean of all variables and using Equations (6.a) and (6.b), we can calculate the equilibrium point between technical efficiency and the size of the leased land area. If we use the values of the full lease samples as the baseline, the technical efficiency will increase from 0.83 to 0.85 and the mean size of leased land will increase from 1.90 mu to 2.17 mu to reach the long-run equilibrium.

These results imply that farmers in Zhejiang Province can still increase their technical efficiency and mean size of leased land before reaching the stable long-run equilibrium. Even though the current average farm size is quite small, farm restructure in the production practice would be the orientation of policy initiative.

5. Conclusion

The transfer of land property in a well-developed market may help to increase economic efficiency and to ensure food security. However, the under-developed land markets and institutional restrictions in many developing economies, including China, often prevent the transfer of land titles and cause a loss of economic efficiency. Land lease, or in other words the transfer of land use rights, might be an alternative tool to improve the economic efficiency of land use.

In particular, a reverse-causality might exist between land lease behavior and productivity, or to be more precisely, between land lease behavior and technical efficiency. Farmers with a higher technical efficiency are more likely to lease more land to enjoy scale effects and to adopt more technologically advanced producing methods, which in turn alter the technical efficiency, usually downward.

Using a panel dataset from Zhejiang Province, China between 1995 and 2002, we proposed a two-step estimation procedure and set up a structural economic model to identify the causalities between the size of the leased land area and technical efficiency and to empirically estimate their complicated relationship. The estimation results are consistent with our hypothesis that the relationship between technical efficiency and the size of the leased land area is endogenous. Specifically, higher technical efficiency on the one hand incentivizes famers to lease more land, and on the other hand, as the size of the leased land area increases, farmers' technical efficiency first increases and later decreases. The system has a stable long-run equilibrium at which technical efficiency and the size of the leased land area are slightly higher than in the current situation. In other words, both technical efficiency and the average size of the leased land area can be slightly improved in the long run.

Finally, we also find that both the output elasticity with respect to land and the returns to scale for lease farmers are significantly higher than those for non-lease farmers, which are also important factors in the explanation of land lease behavior in China.

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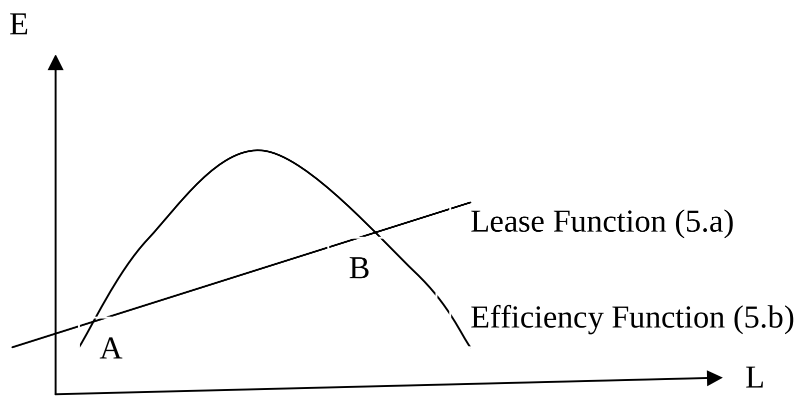

Figure 1. Equilibrium of Lease Activity and Technical Efficiency

Table 1. Estimation Results of the Production Function

	Fixed-Effects Model						Fixed-Effects Stochastic Frontier Model					
	Full Sample		Non-Lease		Lease		Full Sample		Non-Lease		Lease	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t
Ln (Land)	0.3550	1.80*	0.1193	0.55	0.8433	1.29	0.7946	4.68***	0.6036	3.30***	1.6039	3.47***
Ln(Labor)	0.2255	1.07	0.0543	0.23	0.1582	0.20	-0.1779	-1.04	-0.2515	-1.36	-0.8019	-1.75*
Ln(Capital)	0.0698	0.58	0.0876	0.65	0.1058	0.27	0.0412	0.51	0.0443	0.50	0.2046	0.95
Ln (Intermediate)	-0.4014	-1.98**	-0.2474	-1.11	-1.2471	-1.83*	-0.5229	-2.96***	-0.3944	-2.07**	-1.3294	-2.59***
Ln (Land)^2	-0.0084	-0.45	-0.0387	-1.83*	0.1296	2.00**	0.0280	1.69*	-0.0007	-0.04	0.2172	5.66***
Ln(Labor)^2	-0.0228	-0.95	-0.0003	-0.01	0.0207	0.24	0.0387	1.88*	0.0400	1.83*	0.1779	3.35***
Ln(Capital)^2	-0.0024	-0.38	-0.0037	-0.55	0.0187	0.87	0.0053	1.33	0.0047	1.11	0.0094	0.86
Ln (Intermediate)^2	0.0705	3.22***	0.0524	2.11**	0.2109	3.18***	0.0885	4.67***	0.0742	3.58***	0.1817	4.04***
Ln (Land)*Ln(Labor)	0.0116	0.32	-0.0221	-0.55	0.1426	1.12	-0.0830	-2.70***	-0.0888	-2.71***	-0.0899	-1.22
Ln (Land)*Ln(Capital)	0.0200	1.35	0.0240	1.44	0.0264	0.55	0.0306	2.46**	0.0294	2.16**	0.0116	0.43
Ln (Land)*Ln (Intermediate)	-0.0632	-1.90*	-0.0001	0.00	-0.2854	-3.09***	-0.0891	-3.03***	-0.0460	-1.43	-0.2642	-4.14***
Ln(Labor)*Ln(Capital)	0.0183	1.20	0.0199	1.17	-0.0192	-0.38	0.0030	0.26	0.0073	0.58	-0.0477	-1.67*
Ln(Labor)*Ln (Intermediate)	0.0233	0.59	0.0274	0.62	-0.0331	-0.28	0.0346	1.02	0.0427	1.16	-0.0095	-0.12
Ln(Capital)*Ln (Intermediate)	-0.0214	-1.38	-0.0225	-1.30	-0.0661	-1.34	-0.0318	-2.46***	-0.0340	-2.42**	-0.0268	-0.92
Time Trend	-0.0427	-7.81***	-0.0474	-7.21***	-0.0193	-1.42	-0.0121	-1.35	-0.0263	-2.89***	0.0084	0.78
Intercept	6.4440	7.27***	6.3556	6.43***	9.1014	2.97***	8.1267	11.57***	7.9365	10.57***	10.3193	5.23***
							0.0497	[0.0086]	0.0493	[0.0095]	41.1793	[63.0194]
							0.2351	[0.0076]	0.2359	[0.0087]	0.1415	[0.0108]
							0.1745	[0.0262]	0.1729	[0.0293]	0.9966	[0.0052]
Sample Size	2320		1858		462		2320		1858		462	
LR-Test	Chi 2(16) = 433.09***						LR chi2(12) = 147.43***					

Note: *, ** and *** denote the 10%, 5% and 1% levels of significance, respectively.
Standard errors are reported in square brackets.

Table 2. Land Lease Function

Lease Area	IV Tobit Model		Tobit Model	
	Coef.	Z	Coef.	Z
Efficiency	15.470	4.44***	23.201	23.00***
Household Labor Share	-0.596	-0.96	-0.648	-1.06
Household Head Education	-0.627	-3.02***	-0.621	-3.05***
Household Head Age	0.001	0.12	-0.001	-0.10
Ln(Capital)	0.435	4.47***	0.389	4.18***
Share of Machinery in Capital	0.572	0.97	0.841	1.49
Off-Farm Wage	0.019	1.54	0.026	2.30**
Village Rent per mu	0.000	-1.47	0.000	-1.28
Own Land Size	-0.372	-3.31***	-0.304	-2.88***
Household Size	0.342	2.82***	0.320	2.70***
Ln(Levies)	0.302	2.47**	0.363	3.14***
Land Size per Parcel	0.442	1.49	0.555	2.02**
Average Household Education	0.352	0.53	0.395	0.60
Time trend	0.401	4.05***	0.432	4.51***
Intercept	-20.563	-7.79***	-25.605	-17.05***
Test of Exogeneity for Efficiency	chi2(1) = 5.19**			
Log Likelihood	-257.683		-1314.372	

Note: The cluster technical efficiency is used as an instrument for technical efficiency.
*, ** and *** denote the 10%, 5% and 1% levels of significance, respectively.

Table 3. Technique Efficiency Function

	Pooled Regression				Fixed-Effects Regression					
	IV Regression		OLS		IV Regression		OLS		IV Regression	
	Coef.	T	Coef.	T	Coef.	Z	Coef.	t	Coef.	t
Lease Area	0.064	7.28***	0.108	35.86***	0.039	4.20***	0.090	32.06***	0.003	0.30
$(\text{Lease Area})^2$	-0.001	-5.68***	-0.002	-27.26***	-0.001	-3.82***	-0.002	-25.84***		
Land Size per Parcel	-0.022	-4.37***	-0.023	-4.76***	0.006	0.93	-0.008	-1.57	0.014	1.82*
Average Household Education	0.001	0.10	0.006	0.46	0.020	1.07	0.016	0.98	0.021	1.02
Household Head Education	0.003	0.62	0.003	0.69	0.006	0.72	0.013	1.84*	0.003	0.32
Household Head Age	0.000	1.27	0.000	1.30	0.000	-0.11	0.000	0.63	0.000	-0.34
Ln(Capital)	-0.002	-0.79	-0.003	-1.91*	0.002	0.70	0.000	-0.15	0.004	1.26
Share of Machinery in Capital	-0.048	-4.14***	-0.050	-4.66***	-0.003	-0.13	-0.046	-2.54**	0.016	0.65
Share of Grain Area in Land	0.017	1.26	0.032	2.64***	0.023	1.84*	0.025	2.18**	0.027	1.89*
Household Size	-0.002	-0.76	-0.003	-1.13	0.001	0.19	-0.003	-0.88	0.003	0.73
Village Rent Per mu	0.000	-0.17	0.000	0.31						
Own Land Size	-0.001	-0.76	0.001	0.66	-0.003	-1.84*	0.001	1.26	-0.005	-2.60***
Time Trend	-0.009	-4.31***	-0.010	-5.26***	-0.010	-6.54***	-0.012	-8.61***	-0.009	-5.22***
Intercept	0.624	29.24***	0.616	31.34***	0.557	16.61***	0.571	19.14***	0.538	13.72***
F-tests for Fixed-Effects					F(380,1797) = 6.15 ***		F(384, 1868) = 7.32 ***		F(380,1798) =6.40 ***	
Hausman Tests for Exogeneity	chi2(12) = 49.96**				chi2(12) = 58.02***					

Note: Household Labor Share, Off-Farm Wage, Shadow Rent, Shadow Wage, Ln(Levies), and their second –order terms and interaction terms are used as instruments for Lease Area and the square term of Lease Area.
*, ** and *** denote the 10%, 5% and 1% levels of significance, respectively.

Table A1. Explanations to the variables

Variable	Explanation
Cultivated Land	Actual cultivated land area considering multiple crop seasons (mu)
Allocation of Agricultural Land	Share of grain area in total cultivated land. Other land may be used for cash crops
Labor Input	Number of day*works inputted in agricultural production.
Capital	Value of physical capital (yuan)
Allocation of Capital	Share of machinery in physical capital
Intermediate Inputs	Aggregate value of seed, fertilizer and pesticide inputs (yuan)
Lease Area	Size of the leased land area (mu)
Household Size	Number of household members
Household Labor Share	Share of effective labor in the household
Education of Household Head	1=illiterate, 2=elementary school graduate, 3=secondary school graduate, 5=high school graduate and above
Age of Household Head	Age of the household head (years)
Off-Farm Wage	Average off-farm wage in the village (yuan/day)
Village Rent Per mu	Average land lease in the village (yuan/mu)
Own Land Size	Own Land Size (mu)
Levies	Levies of the household (yuan)
Shadow Rent	Shadow lease (yuan/mu), computed from production function
Shadow Wage	Shadow wage(yuan/day), computed from production function
Cluster efficiency	The average efficiency of the other farmers in the village that year
Land Size per Parcel	mu per parcel, measure of land fragmentation
Average Household Education	Share of the household members with secondary school education or above