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The impact of land reallocation on technical efficiency: evidence from China

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Abstract

China's rural reforms expose farm households to an increased risk of administrative land reallocation and adjustment. This study explores the impact of land reallocation on technical efficiency, based on a panel data set from rural households in Zhejiang, Hubei, and Yunnan provinces between 1995 and 2002. Our research indicates that the development of a land rental market could serve as a substitute for administrative land reallocation in optimizing the distribution of land resources. The results from the stochastic frontier production function show that land reallocation does have effects on technical efficiency. The different signs for different provinces indicate that the impact of land reallocation on technical efficiency is an empirical issue and depends on the specific institutional settings and the overall economic environment in each province.

JEL classifications: Q12, Q15

Keywords: Land reallocation; Technical efficiency; Rural China

1. Introduction

Agricultural reform in transition economies, such as China, Vietnam, the former Soviet Union, and Eastern Europe, involves substantial changes in land institutions (e.g., Lerman et al., 2004), and the rapid development of Chinese agriculture has been partly attributed to the success of its land reforms (Fan, 1991; Huang and Rozelle, 1995; Lin, 1992). At the core of Chinese land policy is the coexistence of individual land-use rights with village-level land ownership. Individual rights are intended to motivate farmers to invest in land, while village-level ownership allows officials to reallocate that land periodically and impose other land use adjustments. The initial reforms offered individual rights for a duration of 15 years, but in 1993 that was extended to another 30 years after the expiration of land contracts between farmers and local governments.[1]

In the Chinese land tenure system, households are allocated farmland based on household size, household labor supply, or both. However, household demographics or labor composition constantly change as a result of births and deaths, aging, marriage, family separation, etc. Cultivated land per capita, which was already relatively limited, has declined further due to population growth and conversion of land to nonfarm uses. This decline has been exacerbated by problems of land degradation. Furthermore, although China has codified a robust framework for the protection of land rights, such as the Land Management Law (1998), the Land Contracting Law (2003), and the Property Law (2007), knowledge and practical implementation of these rights are still lagging behind in rural areas (Jin and Deininger, 2009; Tan et al., 2008). The top-down changes to legal and political structures did not solve China's continued struggles with unrest resulting from the appropriation of land by developers and local officials (Kung, 2002). Farmers in many areas are still being forced to relocate by local officials, often illegally, and local cadres still retain large amounts of money intended to be distributed to farmers as compensation for any public-interest land seizures.

The issues related to land reallocation received special attention by economists and policy makers. Some of the existing literature focused on land reallocation policies associated with the land tenure system and the effects these policies have

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[1] The starting point of the initial land tenure differs significantly across provinces and even counties in the same province due to differences in the process of introducing the Household Responsibility System (HRS).

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on land security (Brandt et al., 2002; Liu et al., 1998; Tan et al., 2006). Liu et al. (1998) used village-level data to analyze the frequency of land reallocation and their difference across villages. Brandt et al. (2002) concluded that land tenure security is influenced by land reallocation through the frequency and the extent to which households have been targeted. Tan et al. (2006) used land reallocation as one subgroup of independent variables to find the determinants of land fragmentation and, in turn, its effects on agricultural productivity.

In addition, some authors explored the impacts of land reallocation on investment and other factor markets such as the land rental market. Li et al. (1998) and Jacoby et al. (2002) concluded that land insecurity, which arose from the frequency of land reallocation, dampened farmer incentives to invest in land improvements, especially via the use of organic fertilizers to improve soil fertility. Kung (2002) identified a positive relationship between reallocated land and the demand for land rental; in other words, land reallocation was found to complement the land rental market.

Other studies aimed to improve the understanding of the determinants and extent of land reallocation. Kung (2000) found that the incidence of land reallocation has been significantly influenced by the land endowment, off-farm income opportunities, as well as the population growth rate of the village. This conclusion is consistent with the finding of Yao (2000), who provided evidence on the interaction of land reallocation, in magnitude and frequency, with income levels and the endowment of local land resources. Brandt et al. (2002) concluded that the scope and duration of the dependence of land reallocation is sensitive to the availability of off-farm employment. These studies used either village-level data (Kung, 2000; Yao, 2000) or household-level data (Brandt et al., 2002) to elaborate the relationship between land reallocation and its determinants. Because the data set used in our study contains both village-level and household-level information, it provides us with an opportunity to simultaneously study land reallocation at the farm household level, as well as the potentially important factors at the village level.

A successful transition process in agriculture requires, among other changes, an improvement in productivity and in efficiency as well as functioning input markets in order to make full use of scarce resources (Swinnen and Rozelle, 2006). Land reallocation, which usually takes place without the consent of the farm household, can be expected to lead to a variation in productivity and efficiency in several dimensions. Land reallocation and adjustment could dampen incentives for household investment on the farm and the efficiency of operations within the farm household, but it could also improve efficiency when land is reallocated from lower to higher productivity uses. To date, few studies have provided an empirical analysis of the impacts of land reallocation on the efficiency and output of agricultural production in China.

The goal of this article is to contribute to the ongoing assessment of land reallocation, particularly its effects on the efficiency and output of agricultural production across three different provinces. These provinces have very different resource endowments and technology levels, so heterogeneity of impacts can be expected. Our analysis is based on a panel data set of household and village surveys conducted in these provinces by the Ministry of Agriculture from 1995 to 2002. We first give a descriptive overview of the extent to which land reallocation occurs. We then use instrumental variables (IV) to estimate a fixed-effects model of what determines land reallocation, followed by a stochastic frontier production function to test how that land reallocation influences technical efficiency and production on individual farms.

2. Conceptual framework and econometric model

2.1. Conceptual framework

Land reallocations have been common in rural China for reasons that vary widely across space and time (Brandt et al., 2002). Our focus is on the reallocations that occurred at the end of the 1990s, when land contracts introduced earlier were extended for another 30 years. We are also concerned with ongoing reallocations among farm households by village cadres in pursuit of egalitarian rules, and with expropriation of land for nonfarming purposes or collective production and the corresponding compensation of land afterward. The existing literature concerning the determinants of land reallocation shows that the frequency and scope of land reallocation is affected by changing demographic conditions, access to off-farm and self-employment opportunities, income levels, land endowments and the functioning of the land rental market (Tan et al., 2006; Yao, 2000). In this article, we focus on the role demographic change and the emergence of land rental markets.

First, what is the role of demographic change in land reallocation? The legal framework calls for equal access to land over the 15 (or 30) year land use contracts, but demographic changes occur continuously and village leaders are often under pressure to reallocate land for egalitarian reasons. Such reallocations are usually applied selectively to particular farm households (Brandt et al., 2002; Kung, 2000), but village-wide demographic conditions could influence the demand for reallocation. In this study, variables for both village and household demographic conditions are used.

Second, are land rental markets a substitute for or a complement of land reallocation? Brandt et al. (2002) argue that administrative reallocations are a substitute for the exchange of land that would occur if households rented land to each other because farm rental markets are incomplete or relatively thin. In contrast, Kung (2002) identifies a positive relationship between reallocated and rented land, which implies that land reallocation is a complement for land rental.

Third, how does central government policy affect the determinants and impacts of reallocation? For instance, the Land Management Law (1998) and the Land Contracting Law (2003) both attempt to increase land tenure security for farm households and strengthen their rights to land. A variety of forces influence the implementation of these policies. In our empirical work, we aim to capture how village, household and farm characteristics interact with policy to determine the incidence of land reallocation.

There are quite a few studies that evaluate the productivity and technical efficiency of Chinese agricultural production (Brümmer et al., 2006; Huang and Rozelle, 1995; Lin, 1992). To the best of our knowledge, however, few of them have empirically assessed the influence of land reallocation on productivity and technical efficiency. This study uses a two-stage procedure to identify these effects, using predicted reallocations from a first-stage model, plus conventional physical inputs such as cultivated land, labor, capital, fertilizer and seed, together with other control variables to estimate a stochastic frontier production function from which we then calculate farm technical efficiency.

The three provinces in our study are characterized by differences in resource endowments and in levels of economic development, so we expect heterogeneity in the determinants and effects of land reallocation. We are particularly interested in its interaction with land rental. Although land leasing has been legally sanctioned and encouraged by the government, the extent to which land rental markets are developed differs across China, and whether it complements or substitutes administrative land reallocation is an empirical question. Having controlled for these varying conditions, if frequent reallocation of land proves to be detrimental to output, then future reforms should be oriented to guarantee land security. On the other hand, land reallocations could have improved the allocation of land, perhaps because land rental markets failed to allow higher-productivity farmers to take over land in lower-productivity uses. Thus, the direction and magnitude of the impact of land reallocation on production and efficiency should be determined based on an empirical analysis.

2.2. *Econometric model*

According to the conceptual framework described above, we apply the following two-stage model to analyze the determinants of land reallocation and its impact on farm production in rural China.

Stage 1: Fixed-effects model[2] with IV estimation

$$Y_{it} = \alpha Z_{it} + \theta L_{it} + c_i + \varepsilon_{it} \tag{1}$$

$$\text{Cov}(L_{it}, \varepsilon_{it}) \neq 0 \tag{2}$$

$$\text{Cov}(I_{it}, \varepsilon_{it}) = 0 \tag{3}$$

$$\text{Cov}(L_{it}, I_{it}) \neq 0. \tag{4}$$

In Eq. (1), Y_{it} is a proxy for land reallocation for household i at time t as shown. Z_{it} is a vector of exogenous variables that describe the social and economic development of a village, the household and farm characteristics, and relevant state policy variables. L_{it} represents potentially endogenous variables that might be correlated with $\varepsilon_{it} \sim N(0, \sigma_\varepsilon)$, the random error term in Eq. (1). I_{it} are excluded instrumental variables that do not appear as regressors in Eq. (1), are uncorrelated with ε_{it} in Eq. (3), and possibly correlated with L_{it} in Eq. (4). α and θ are the associated vectors of the parameters to be estimated. c_i represents the unobserved time-invariant household effects.[3] All estimations are carried out with Stata (Version 10.0), using cluster-robust estimates of the variance–covariance matrices (Schaffer, 2007).

Stage 2: Normal/Half-normal Stochastic Frontier Production

$$Q_{it} = f(X_{it}, T; \beta) + v_{it} - u_{it} \tag{5}$$

$$u_{it} \sim N^+(0, \sigma_{u_{it}}) = N^+(0, \sigma_u e^{rJ_{it}}), \tag{6}$$

where Q_{it} represents the value of aggregated farming output[4] for farm i in year t, $f(X_{it}; \beta)$ is a suitable production function form (a translog specification in our study), X_{it} is the vector of conventional inputs, T is a linear time trend to capture technological progress, and β is the associated vector of technology parameters to be estimated. v_{it} is a random error term assumed to be i.i.d. $N(0, \sigma_v)$. The error terms u_{it} are nonnegative random variables that account for technical inefficiency in the production. They are half-normally distributed with the location parameter μ set equal to zero, and parameter $\sigma^2_{u_{it}}$ to be estimated. This error term u_{it} is allowed to be heteroscedastic by introducing a multiplicative relationship between the variables J_{it} responsible for heteroscedasticity and the common distribution parameter σ_u(Eq. (6)). J_{it} can be interpreted as a vector of variables used to explain variation in technical inefficiency. In particular, we also include the predicted value of the change in arable land (due to land reallocation) from stage 1 of the model. γ is the associated parameter vector of the determinants of technical inefficiency that is to be estimated.

3. The incidence of land reallocation and data description

The database used in this study is drawn from a fixed-point survey data series across Zhejiang, Hubei, and Yunnan provinces conducted annually by Research Center for Rural Economy (RCRE), China. The three provinces were chosen to reflect the diversity of China's agricultural production. Zhejiang province is one of the richest Chinese provinces in the East, Hubei province represents the central middle-income region,

[2] The Breusch–Pagan test and the Hausman test are used to compare random-effects and fixed-effects specifications. The resulting chi-squared statistic strongly rejects the random effects model at the 1% significance level, suggesting that the unobserved factors are correlated with the explanatory variables in the estimations.

[3] These effects include location of the household and farm, and the quality level of farm land, etc.

[4] Farming output includes (1) grain crops, cash crops, and other crops; (2) fruits, silkworm cocoon, tea, crude drugs, and vegetables.

Table 1
Summary statistics of land reallocation and land rental market (1995–2002)

Variable	Zhejiang		Hubei		Yunnan	
Village level						
No. of villages [a]	72		120		40	
Villages with aggregate land reallocation ≤ −5 mu	37		48		20	
Villages with aggregate land reallocation (−5, 5) mu	31		68		19	
Villages with aggregate land reallocation ≥5 mu	4		4		1	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Household level						
Share of households with land reallocation (%)	18.09	3.98	15.47	3.08	11.82	9.87
Gained land due to land reallocation (mu/hh)	1.26	0.17	1.28	0.19	1.12	0.33
Lost land due to land reallocation (mu/hh)	−1.19	0.18	−1.48	0.10	−1.36	0.27
Arable land per household (mu/hh)	2.16	1.29	4.08	1.56	6.64	7.75
Land rented out per household (mu/hh)	0.13	0.15	0.06	0.11	0.07	0.09
Land rented in per household (mu/hh)	0.17	0.19	0.06	0.11	0.06	0.08
No. of observations	1,635		4,849		2,260	

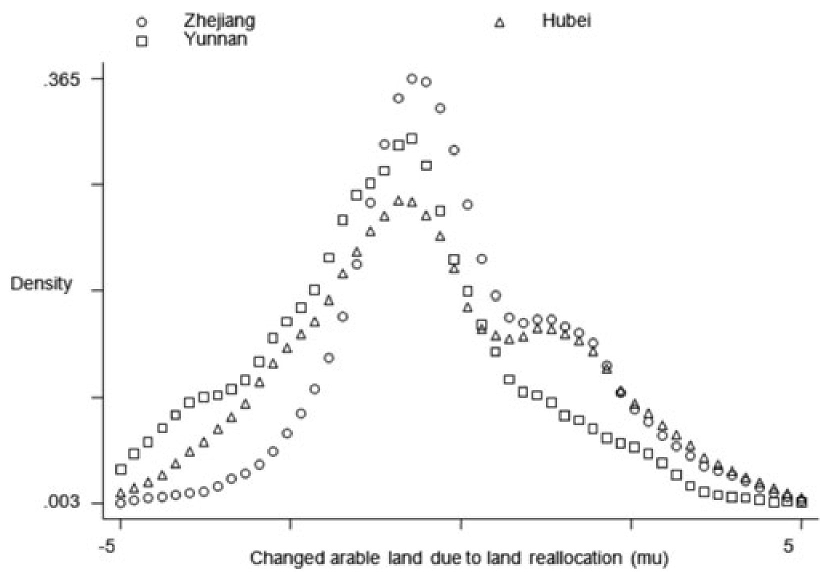
[a] At village level, the data set includes balanced panel data. Nine villages of Zhejiang, fifteen villages of Hubei, and five villages of Yunnan are the survey sites for each year (1995–2002). Thus, there are 72, 120, and 40 villages in Zhejiang, Hubei, and Yunnan, respectively, by pooling the sampled villages from 1995 to 2002.

and Yunnan province belongs to West China and is one of the poorest regions in the country.[5] The sample collection proceeds in a stratified way for the village data. After that the household data of the respective villages are randomly selected. Initially, every county is stratified by annual net income per capita into upper, middle, and lower groups (Benjamin et al., 2005). Representative villages in each group are then chosen according to geographic (plain, hilly, or mountainous area), location (city, suburb, or not), and economic characteristics. We use individual household data and the associated village data covering the period from 1995 to 2002.[6] The data constitute a balanced panel at the village level, with nine villages in Zhejiang, fifteen villages in Hubei, and five villages in Yunnan. At the household level, the data set is unbalanced; on average, there are 204 households per year in Zhejiang, 606 in Hubei, and 283 in Yunnan. The individual household data contain detailed information on agricultural production operations and farm features, as well as personal and household characteristics. The village data reflect the village's characteristics and its social and economic development.

Table 1 presents the summary statistics on land reallocation and land rental markets over the sample period. Land reallocation is quantitatively measured as area of changed arable land of the farm household due to land reallocation within a year. We illustrate the distribution of the reallocation at the village level over time, and the number of villages with respect to their aggregate land reallocation in three categories over the sample period is counted here. The result shows that roughly half of the village observations have experienced significant loss of arable land during land reallocation. Sample mean values for the three provinces are reported here; summary statistics by year did not reveal any obvious trend. In general, land reallocation or adjustment occurred in almost all the sampled villages more than once in the period from 1995 to 2002. On average, 18.09% of households had their land reallocated in Zhejiang, 15.47% in Hubei, and 11.82% in Yunnan. This also implies that in all three provinces land reallocation in most cases is probably not a village-wide reallocation but a partial adjustment. As to the magnitude of land reallocation, gained land due to land reallocation is 1.26 mu per household in Zhejiang, 1.28 mu per household in Hubei, and 1.12 mu per household in Yunnan. Lost land due to land reallocation is 1.19 mu per household in Zhejiang, 1.48 mu per household in Hubei, and 1.36 mu per household in Yunnan. However, when compared with the average land endowment of the farm households, the different relative impacts of land reallocation on land endowment become obvious. A farm household in Zhejiang on average has arable land 2.16 mu, while the quantity is 4.08 mu in Hubei and 6.64 mu in Yunnan. Reallocated land accounts for more than half of that farm household's arable land in Zhejiang, and that is roughly one-third in Hubei, and one-sixth in Yunnan. Land rented out is on average 0.13 mu per household in Zhejiang, 0.06 mu per household in Hubei, and 0.07 mu per household in Yunnan. Land rented in is on average 0.17 mu per household in Zhejiang, 0.06 mu per household in Hubei, and 0.06 mu per household in Yunnan. Land rental activities are much more important in Zhejiang than in the other two provinces. Fig. 1 presents a kernel density estimate of arable land changes due to land reallocation by provinces from 1996 to 2002. There is not much difference in the distribution for the three provinces. Zhejiang shows the narrowest distribution of land being reallocated, while there was a comparatively larger variation in land reallocation in Hubei and Yunnan. There is a relatively fatter left-side tail in Yunnan, reflecting a comparably severe loss of land due to land reallocation for farmers.

[5] Per capita Gross Regional Product in 2004 amounts to 23,942 RMB, 10,500 RMB, and 6,733 RMB, respectively (NBS, 2006).

[6] A one-year lag of input variables is used as excluded instrumental variables in the stage 1 model, so the 1995 data were automatically dropped out. The estimated results presented in the following are from 1996 to 2002.



Note: Observations with zero value of changed arable land due to land reallocation are not accounted in the figure.

Fig. 1. The kernel density of changed arable land due to land reallocation by provinces (1996–2002).

According to our conceptual framework, the following factors that affect land reallocation are introduced in the stage 1 model. Variables that reflect the social and economic development of the village include annual net income per capita representing the economic conditions of the village; birth and death rate of the village, share of people who migrated into and out of the village (with change of the location of household registration) within the year, which are controlling for effects of demographic change; share of arable land rented out during the year used as the proxy of the land rental market in the local village; area of arable land per capita, which index land endowment of the village; and share of households doing business outside the village, and the number of enterprises in the village by the end of year, signaling the availability of off-farm employment and income opportunities (one-year lag of these two variables has been used as excluded instruments in the estimation considering the potential endogeneity problem[7]). In addition, two household-level variables, number of rural permanent residents and sown area of arable land, are used to capture the effects of household and farm characteristics on land reallocation. Taking into account the potential endogeneity problem of the sown area of arable land, a lag of one period for the production input factors of labor, land, intermediate input, and capital are introduced as excluded instruments. Furthermore, six yearly dummy variables are included to capture the impact of state policy on land reallocation, with the year 1996 as the reference period[8].

For the stage 2 model, the farming output is measured as an aggregate value for grain crops, cash crops, other crops, fruits, silkworm cocoon, tea, crude drugs, and vegetables. The four conventional input variables are labor, land, intermediate input, and capital. Labor input is the total annual working days allocated to planting production. The total sown area for grain crops, cash crops, and other crops is used for the land variable. The intermediate input sums up the purchase value of seeds, fertilizer, agricultural diesel oil, plastics, and pesticides used in agricultural production. Capital is measured as the total original value of fixed-capital assets for agricultural production at the end of the year, and includes draught animals, production tools, and machinery. In addition, a linear time trend variable is introduced to capture changes in technology. Monetary values for all variables are deflated with respect to 1995 constant prices.

Variables explaining the variation in technical inefficiency consist of the predicted value of changed arable land due to land reallocation obtained from the stage 1 estimation. The predicted value is separated into two new variables (with positive and negative values retained respectively) that measure the effects of gaining or losing arable land due to land reallocation on technical inefficiency. We allow the two effects on technical inefficiency to be different in direction and/or in magnitude. Other variables include a dummy variable with value 1 if any of the household members is a township or village cadre, and otherwise 0; the share of rural laborers with primary school education, secondary school education, high school education and above (share of illiterate rural laborers as reference) in a household; the share of rural laborers licensed with professional titles; and the share of plots with size between 0.5 and 1 mu[9],

[7] We thank one anonymous referee who pointed out the potential endogeneity problem of these two variables.

[8] Data for the year 1995 were dropped because one period of lagged variables is used.

[9] 1 mu = (1/15) hectare in China.

Table 2
Descriptive statistics of the variables

Description	Symbol	Zhejiang		Hubei		Yunnan	
		Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Stage 1 model							
Dependent variable							
Area change of arable land due to land reallocation (mu)	*Land_real*	−0.029	0.590	−0.067	0.674	−0.121	0.625
Independent variables							
Social and economic development of village							
Net income per capita (1000 Yuan/person)	*Income_pc*	4.070	2.268	1.599	0.514	1.300	1.213
Birth rate (‰)	*Birth*	7.971	3.760	7.745	3.824	15.086	6.075
Death rate (‰)	*Death*	7.197	2.990	6.724	3.018	6.978	2.391
Ratio of migration into the village (%)	*Migr_in*	0.850	0.730	0.486	0.320	0.896	0.408
Ratio of migration out of the village (%)	*Migr_out*	2.483	10.764	0.430	0.737	0.141	0.290
Arable land per capita (mu/person)	*Land_pc*	0.761	0.330	1.079	0.334	1.597	1.460
Ratio of arable land rented out (%)	*Land_rent*	8.109	8.977	1.255	2.509	2.316	4.353
Ratio of households doing business outside the village (%)	*Business*	8.129	7.105	7.189	6.109	1.129	1.487
Number of enterprises in village	*Enterprise*	12.266	21.040	4.648	8.507	4.292	16.767
Farm and household characteristics							
Number of rural permanent residents (person)	*Residents*	3.751	1.254	4.125	1.531	4.457	1.379
Sown area of arable land (mu)	*Land_sown*	5.119	4.294	9.052	4.652	10.847	12.259
Stage 2 model							
Dependent variable							
Aggregate value of farming output (Yuan)	*Q*	5,002.152	8,941.107	5,520.896	5,166.022	5,610.125	3,169.587
Independent variables							
Labor (days)	*a*	115.794	82.880	274.013	138.031	364.858	181.977
Land (mu)	*l*	5.119	4.294	9.052	4.652	10.847	12.259
Intermediate input (Yuan)	*i*	848.017	980.021	808.446	655.719	577.721	720.413
Capital (Yuan)	*k*	1,898.035	5,708.085	968.522	1,108.936	1,091.409	975.397
Positive predicted value from stage 1 (mu)	*Pred_posi*	0.093	0.242	0.165	0.306	0.064	0.150
Negative predicted value from stage 1 (mu)	*Pred_nega*	−0.122	0.217	−0.232	0.355	−0.184	0.273
Share of plots with size 0.5–1 mu (%)	*Plot_1*	30.119	26.564	30.481	24.418	33.150	24.197
Share of plots with size 1–2 mu (%)	*Plot_2*	23.010	32.451	24.214	24.860	19.074	20.055
Share of plots with size 2–3 mu (%)	*Plot_3*	4.689	17.757	5.930	15.721	4.931	10.087
Share of plots with size 3–4 mu (%)	*Plot_4*	0.061	2.472	1.167	6.838	1.818	6.839
Share of plots with size 4–5 mu (%)	*Plot_5*	0.020	0.824	0.442	5.610	0.791	3.895
Share of plots with size > 5 mu (%)	*Plot_6*	0	0	0.088	1.898	0.205	1.613
Fraction of laborers graduated from elementary school (%)	*Elementary*	44.320	32.559	39.034	33.834	52.006	35.693
Fraction of laborers graduated from secondary school (%)	*Secondary*	33.577	30.042	38.116	32.727	16.630	25.200
Fraction of laborers graduated from high school and above (%)	*High*	6.573	16.927	6.592	18.260	2.131	10.103
Fraction of laborers with skilled abilities (%)	*Skill*	4.016	12.804	2.688	11.156	2.481	9.953
Cadre household (dummy, 1 = yes)	*Cadre*	0.092	0.289	0.080	0.271	0.013	0.114
No. of observations		1,635		4,849		2,260	

1 and 2 mu, 2 and 3 mu, 3 and 4 mu, 4 and 5 mu, and larger than 5 mu (share of plots with size smaller than 0.5 mu is used as a reference for this category).

In Table 2, the descriptive statistics of the variables are listed for the stage 1 and stage 2 models. From the statistics, we observe very different characteristics and social and economic development levels at both the household and village level across the three provinces. The share of arable land rented out in the village, which is a proxy for the role of activities on the land rental market, is on average 8.109% in Zhejiang, while only 1.255% in Hubei and 2.316% in Yunnan. These values confirm the judgment of relatively big differences in the development of the land rental market across the regions.

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 divided by their respective sample means; the time trend variable is scaled to have a mean of zero. Hence, estimated first-order parameters of the translog production frontier can be estimated as elasticities at the point of normalization, i.e., at the sample mean.

Table 3
Determinants of land reallocation with fixed-effects models

	Zhejiang		Hubei		Yunnan	
	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.
Income_pc	0.014	(0.020)	−0.046	(0.056)	0.446***	(0.100)
Birth	0.004	(0.005)	0.010	(0.006)	−0.007	(0.004)
Death	−0.008	(0.008)	0.011	(0.007)	−0.006	(0.008)
Migr_in	−0.012	(0.030)	0.122*	(0.061)	−0.303**	(0.093)
Migr_out	−0.000	(0.002)	0.027	(0.024)	0.178	(0.108)
Land_pc	1.273	(0.954)	0.186	(0.720)	3.083*	(1.234)
Land_pc2[a]	−0.362	(0.445)	0.280	(0.335)	−0.335**	(0.127)
Land_rent	−0.005	(0.003)	−0.029*	(0.012)	−0.005	(0.010)
Business	0.008	(0.004)	−0.081**	(0.028)	0.012	(0.048)
Enterprise	−0.000	(0.002)	0.038**	(0.013)	0.006	(0.004)
D_1997	−0.005	(0.048)	0.062	(0.053)	−0.079	(0.042)
D_1998	−0.049	(0.057)	−0.179*	(0.072)	−0.061	(0.062)
D_1999	0.065	(0.049)	−0.136*	(0.061)	−0.368***	(0.078)
D_2000	−0.141*	(0.064)	−0.180*	(0.073)	−0.164	(0.094)
D_2001	−0.068	(0.072)	−0.171*	(0.074)	−0.247**	(0.094)
D_2002	−0.226*	(0.092)	−0.064	(0.080)	−0.313**	(0.099)
Residents	0.006	(0.024)	0.218***	(0.050)	0.046*	(0.019)
Land_sown	−0.035	(0.022)	−0.174***	(0.039)	0.004***	(0.001)
N	1,619		4,834		2,238	
F statistic	$F(18,1313) = 2.74$		$F(18,3989) = 1.65$		$F(18,1845) = 6.29$	
P-value	<0.001		0.041		<0.001	
sigma_u	0.403		0.903		1.484	
sigma_e	0.491		0.800		0.525	
rho	0.403		0.560		0.889	
Model diagnostics: Results of hypothesis tests with fixed-effects IV estimation						
1. Endogeneity test of endogenous regressors						
H_0: Land_sown can actually be treated as exogenous						
χ^2	$\chi^2(1) = 19.676$		$\chi^2(1) = 47.411$		$\chi^2(1) = 3.099$	
P-value	<0.001		<0.001		0.078	
H_0: Business can actually be treated as exogenous						
χ^2	$\chi^2(1) = 1.080$		$\chi^2(1) = 10.051$		$\chi^2(1) = 1.781$	
P-value	0.299		0.002		0.182	
H_0: Enterprise can actually be treated as exogenous						
χ^2	$\chi^2(1) = 0.051$		$\chi^2(1) = 0.847$		$\chi^2(1) = 12.081$	
P-value	0.822		0.358		<0.001	
2. IV redundancy test (LM test of redundancy of specified instruments)						
H_0: Instruments of lagged labor, intermediate and capital input are redundant						
χ^2	$\chi^2(3) = 5.424$		$\chi^2(6) = 17.841$			
P-value	0.143		0.007			
3. Underidentification test (Kleibergen–Paap rk LM statistic)						
H_0: The specified model is underidentified						
χ^2	$\chi^2(1) = 6.095$		$\chi^2(4) = 67.201$		$\chi^2(1) = 30.918$	
P-value	0.014		<0.001		<0.001	
4. Overidentification test of all instruments (Hansen J statistic)						
H_0: Instruments used in the model are valid instruments						
χ^2			$\chi^2(3) = 0.907$			
P-value			0.824			

[a]Land_pc2 is the square of arable land per capita (Land_pc).
$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

4. Empirical results

4.1. Fixed-effects model with instrumental variables estimations

Before presenting the main results, we give an overview of selected diagnostic tests in the lower half of Table 3. We first test the endogeneity of the potentially endogenous regressors. The test statistics suggest that share of households doing business outside the village (Business) and number of enterprises in the village (Enterprise) both can be treated as exogenous in Zhejiang, whereas Business is endogenous in Hubei, and Enterprise is endogenous in Yunnan; the cultivated area of arable land can actually be treated as exogenous in Yunnan, while an

Table 4
Estimated results from the translog stochastic frontier production functions[a]

	Zhejiang		Hubei		Yunnan	
	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.
Frontier function						
t	0.025	(0.013)	0.016***	(0.004)	−0.029***	(0.007)
ln(a)	0.510***	(0.054)	0.073***	(0.020)	0.088**	(0.033)
ln(l)	0.211***	(0.044)	0.505***	(0.022)	0.155***	(0.028)
ln(i)	0.247***	(0.051)	0.253***	(0.014)	0.367***	(0.020)
ln(k)	0.026	(0.017)	0.000	(.)	0.099***	(0.019)
$t\times t$	−0.012	(0.006)	−0.014***	(0.004)	0.003	(0.005)
0.5ln(a)×ln(a)	0.190***	(0.046)	0.152***	(0.038)	0.072	(0.055)
0.5ln(l)×ln(l)	0.013	(0.031)	0.250***	(0.051)	−0.114***	(0.024)
0.5ln(i)×ln(i)	0.110*	(0.050)	0.030	(0.017)	0.054***	(0.013)
0.5ln(k)×ln(k)	0.011	(0.007)	0.006	(0.006)	0.018	(0.014)
t×ln(a)	0.007	(0.011)	−0.001	(0.007)	0.014	(0.010)
t×ln(l)	0.012	(0.011)	−0.023**	(0.008)	−0.049***	(0.009)
t×ln(i)	0.006	(0.011)	0.034***	(0.006)	−0.018***	(0.005)
t×ln(k)	−0.014***	(0.004)	−0.001	(0.003)	−0.009	(0.005)
ln(a)×ln(l)	0.005	(0.030)	−0.242***	(0.034)	0.035	(0.036)
ln(a)×ln(i)	−0.208***	(0.039)	0.005	(0.025)	−0.035	(0.024)
ln(a)×ln(k)	0.019	(0.013)	−0.074***	(0.014)	−0.094***	(0.020)
ln(l)×ln(i)	0.107***	(0.032)	0.025	(0.025)	−0.028	(0.022)
ln(l)×ln(k)	−0.012	(0.013)	0.100***	(0.017)	0.016	(0.017)
ln(i)×ln(k)	−0.021	(0.013)	−0.036**	(0.012)	0.056***	(0.012)
intercept	0.350***	(0.041)	−0.011	(0.017)	0.260***	(0.027)
Inefficiency model						
Pred_posi	3.771***	(0.852)	−2.648**	(0.869)	−8.795***	(1.997)
Pred_nega	8.782	(8.919)	2.193***	(0.619)	0.568	(0.438)
Plot_1	0.009	(0.018)	−0.001	(0.005)	0.005	(0.004)
Plot_2	0.045***	(0.013)	−0.007	(0.006)	−0.039***	(0.009)
Plot_3	−0.277	(0.270)	−0.097**	(0.034)	−0.011	(0.011)
Plot_4	0.046	(0.104)	−0.042	(0.034)	−0.010	(0.011)
Plot_5	−0.333	(276.513)	−0.002	(0.021)	−0.089*	(0.040)
Plot_6	0.000	(.)	−0.212	(0.639)	−0.009	(0.045)
Elementary	0.015	(0.014)	−0.009*	(0.004)	−0.021***	(0.003)
Secondary	0.017	(0.019)	−0.012*	(0.005)	−0.031***	(0.007)
High	0.010	(0.027)	−0.019	(0.010)	−0.005	(0.011)
Skill	0.029	(0.025)	0.021**	(0.008)	−0.028	(0.038)
Cadre	−27.767	(1,278.717)	−0.368	(0.536)	−2.287	(2.388)
intercept	−8.687***	(1.650)	−2.112***	(0.391)	−0.643*	(0.267)
N	1635		4849		2260	
log likelihood	−732.54		−2967.04		−964.41	
sigma_v	0.372	(0.007)	0.440	(0.005)	0.349	(0.007)

[a] t = time; ln(a) = natural logarithm of a; ln(l) = natural logarithm of l; ln(i) = natural logarithm of i; ln(k) = natural logarithm of k.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

endogenous regressor problem exists in Zhejiang and Hubei. In addition, we perform the IV redundancy test for Zhejiang and Hubei to identify whether the excluded instruments for lagged labor, intermediate and capital inputs are redundant. The results show that these variables are redundant only for Zhejiang. The results of the underidentification and overidenfication tests of all the instruments are also listed in Table 3. Finally, we examine whether the fixed-effects model or random-effects model is to be used for the estimations. The resulting chi-square statistics from both the Breusch–Pagan test and the Hausman test strongly reject the random-effects model at the 1% significance level, suggesting that the unobserved fixed effects are likely correlated with the explanatory variables in the estimations.

The upper half of Table 3 reports the estimated results. Demographic change has no effect on land reallocation in Zhejiang, whereas it does impact land reallocation in Hubei and Yunnan. The number of rural permanent residents in the household (Residents) significantly positively affects land reallocation in Hubei and Yunnan, indicating that demographic change within a farm household is one important factor for land adjustments in the village. This is consistent with the initial land allocation policies implemented in rural China, according to which land allocation to the households should be mainly based on numbers of rural residents or rural laborers (Brandt et al., 2002; Liu et al., 1998). Among the village-level variables that represent demographic change, only the share of people who migrated

Table 5
Level of technical efficiency from 1996 to 2002 by provinces

	1996	1997	1998	1999	2000	2001	2002	Average
Zhejiang	0.963	0.952	0.949	0.937	0.971	0.963	0.972	0.957
Hubei	0.911	0.912	0.912	0.909	0.916	0.918	0.915	0.913
Yunnan	0.845	0.869	0.872	0.847	0.875	0.885	0.875	0.867

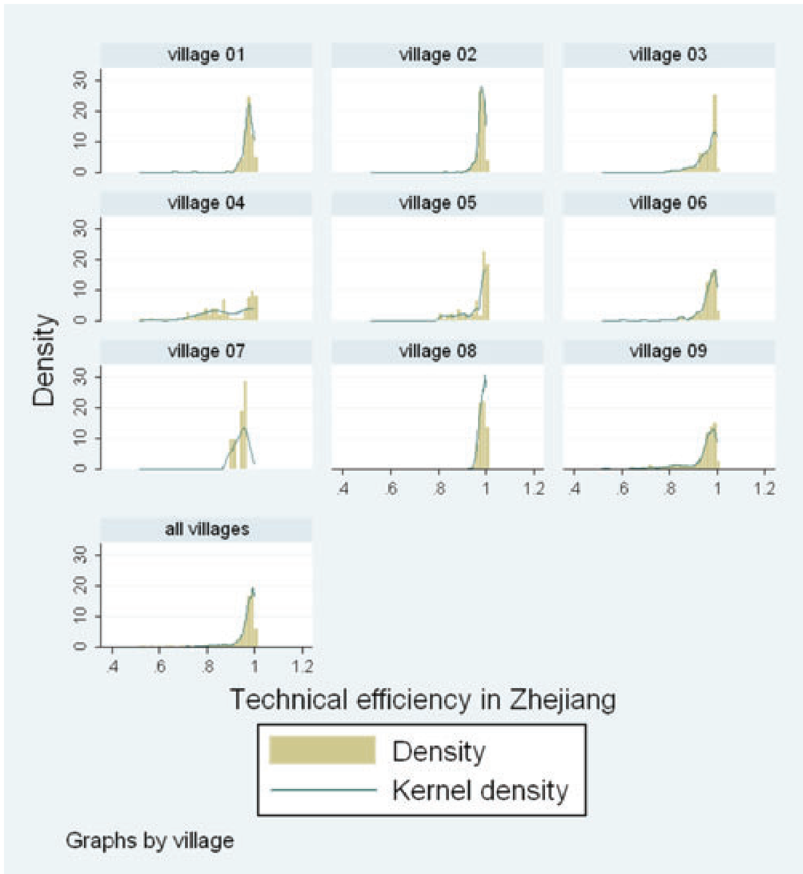


Fig. 2. The kernel density of technical efficiency across villages in three provinces (1996–2002).

into the village (Migr_in) is significant. The positive sign of the coefficient in Hubei might indicate that there exists some flexibility with regard to preserved arable land (jidong tian in Chinese), which can be allocated to the newcomers, while the situation might be contrary in Yunnan, judged from the negative parameter estimate of Migr_in for this province. Share of arable land rented out (Land_rent), which is a proxy of the development of the land rental market, has negative effects on land reallocation in all three provinces; however, the coefficients are insignificant in Zhejiang and Yunnan. We thus find at least for Hubei that the land rental market acts as a substitute for administrative land reallocation in optimizing land resources among farm households. The economic conditions of the village (Income_pc) positively affect land reallocation only in Yunnan, but their effect is not significant in Zhejiang and Hubei. Although the coefficients of arable land per capita (Land_pc) and its square (Land_pc2) are not significant in Zhejiang and Hubei, respectively, the Wald test shows that they are jointly significant in both provinces. The estimates for the three provinces are in accordance with previous research results that abundant land resources facilitate more intensive land reallocation in the village. Off-farm employment opportunities, as measured by the share of households doing business outside the village (Business) and the number of enterprises in the village (Enterprise), only affect land reallocation in Hubei, while they have no effect in Zhejiang and Yunnan. The negative coefficient estimate for Business in Hubei suggests that off-farm income opportunities alleviate the pressure of requests for land during land adjustments. The positive estimate for the parameter on Enterprise could be explained by the fact that a fraction of farm households quit agricultural production and work in the enterprises located in the village and, as a result, farm households that stay in agriculture obtain the extra land reallocated from those who exit. Farm size (Land_sown) only affects land reallocation in

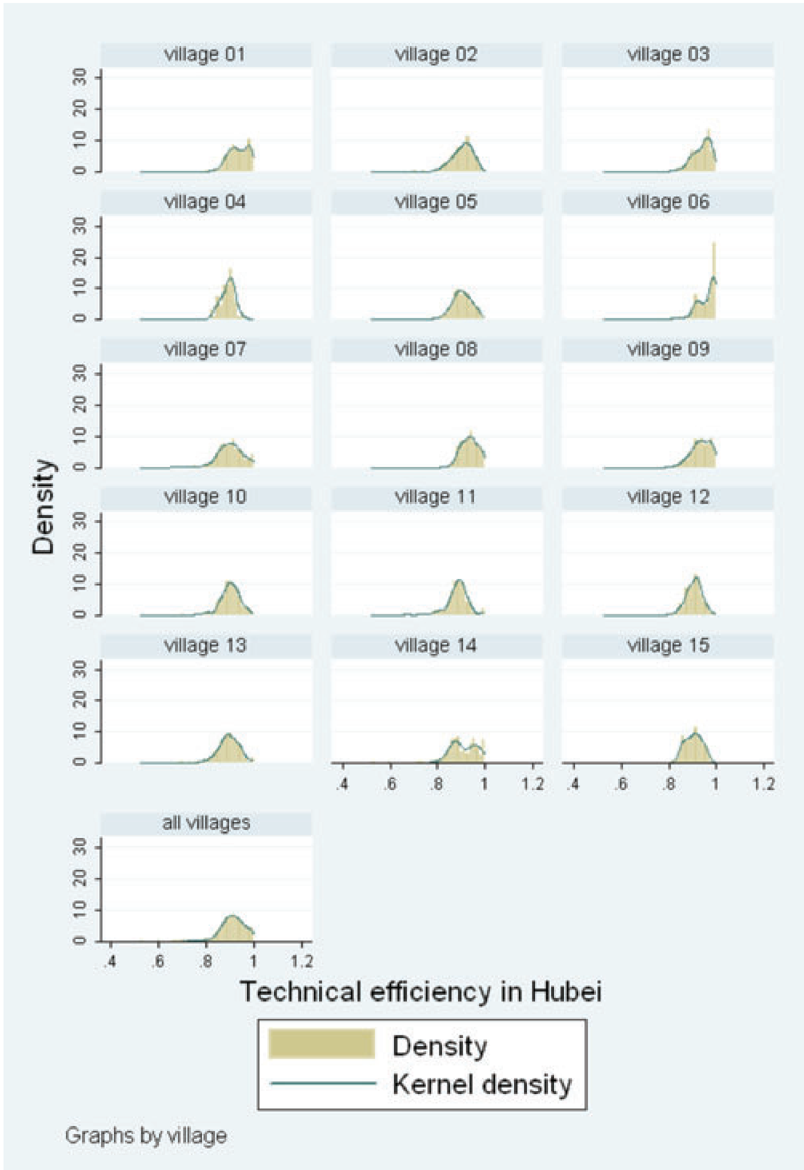


Fig. 2. Continued

Hubei and Yunnan. The impact is negative in Hubei and positive in Yunnan, which implies the different effects of land/labor ratio within farm households for these two provinces. The signs of the majority of yearly dummy variables are negative and some of them become statistically significant from 1998 on in all the three provinces, implying that the land tenure, to a large extent, has been secured after the announcement of the extension of the land use right for another 30 years.

4.2. The SFA production function

The translog stochastic frontier production function is estimated in the stage 2 model. Several hypotheses regarding the specification have been tested first. Our results reject the hypothesis that a Cobb–Douglas frontier, with its implicit strong assumptions, e.g., constant partial production elasticities and unit elasticity of substitution between the inputs, is an adequate representation of the agricultural production in the three provinces. The null hypothesis of no technical inefficiency effects in the model is also rejected, indicating that the technical inefficiency term should be considered in the estimations of the technology.

Table 4 presents estimates of the parameters for the translog production function. Over the study period, average technical change is estimated at a yearly rate of 1.6% in Hubei. Insignificant technical progress is observed on average in Zhejiang, while there seems to be technical regress at the sample mean in Yunnan, as implicated by the significantly negative coefficient for the linear time trend. The overall model quality, as judged by

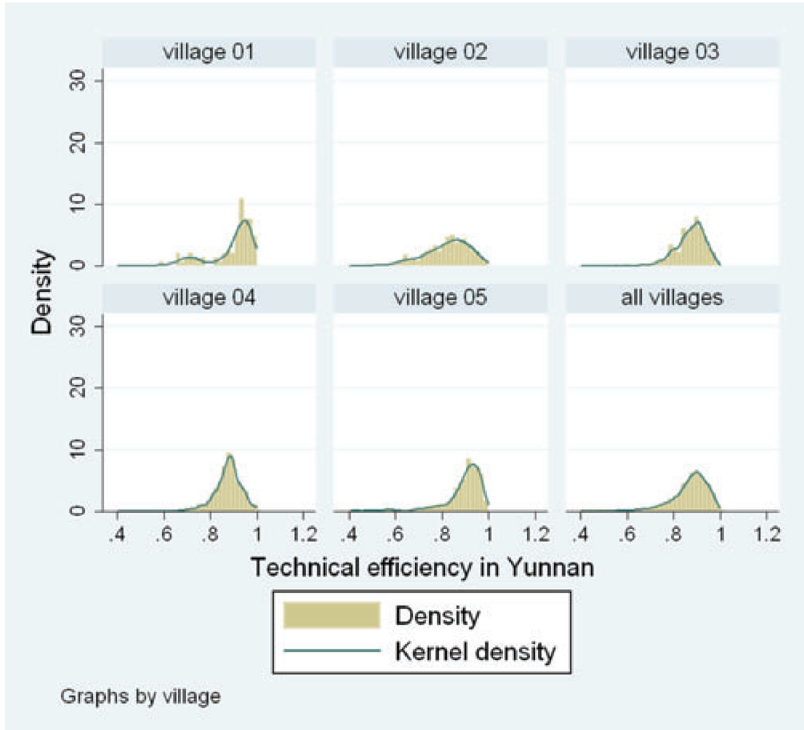


Fig. 2. Continued

the *t*-ratios, seems satisfactory. All the first-order coefficients of the inputs have the expected signs, and thus indicating positive partial production elasticities at the sample mean.

In terms of the magnitude of these elasticities at the sample mean, the most important factors are labor, land, and intermediate inputs. In particular, the structure of the labor elasticities is consistent with the level of regional development of the three provinces. It can be expected that opportunity costs of labor are relatively low in the less developed provinces of Hubei and Yunnan, which, in turn, implies that farms allocate comparatively more labor to agricultural production than farms in relatively developed coastal regions such as Zhejiang. Our results indicate that agricultural production in Hubei is very land intensive, with an estimated elasticity of 0.51 at the sample mean. The corresponding elasticity of land is still substantial in Zhejiang and Yunnan, with point estimates of 0.21 and 0.16 at the sample mean, respectively. The lowest partial production elasticity is observed for capital. Contrary to labor, this is an indicator of the relative scarcity of capital in agricultural production. Because the elasticities correspond to ratios of an input's marginal product to its average product, a small elasticity can also be attributed to high average factor productivity. This will be the case when a factor such as capital is scarce in Chinese agriculture. Intermediate inputs account for the most important factor in Yunnan. In addition, the sum of the input elasticities provides information about scale economies with results of 97% in Zhejiang, 83% in Hubei, and 71% in Yunnan. These indicate that the production technology exhibits decreasing returns to scale for the sample mean in Hubei and Yunnan.

4.3 Technical efficiency

After estimation of the stochastic frontier production function, we calculate technical efficiency for each farm household over the whole observation period. Table 5 reports the level of technical efficiency for the three provinces over time and Fig. 2 presents the kernel density distribution of technical efficiency for each of the sampled villages from 1996 to 2002. Our results show that technical efficiency stays relatively constant with moderate increase during the study period, while the average level of the technical efficiency term mirrors the regional level of economic development. Fig. 2 illustrates the variations in technical efficiency across villages and households within the villages. The majority of rural households in Zhejiang province operate close to the agricultural production frontier. However, for the households in Hubei and Yunnan, further growth of agricultural production through the improvement of technical efficiency could be expected.

In the lower part of Table 4, we present the determinants for the variation of farm households' inefficiency. The parameters indicate the direction of the effects these variables have on the inefficiency level. Hence, a negative parameter estimate for some variables indicates a positive effect on technical efficiency.

The coefficients of predicted changed arable land due to land reallocation indicate negative effects on technical efficiency in Zhejiang and positive effects in Hubei and Yunnan. The implication is that the impact of land reallocation on technical efficiency is an empirical issue. In the case of Hubei and Yunnan, land reallocation could act as a substitute for the land rental market, which has been shown in the result of stage 1 model estimation, to optimize the allocation of land resources and hence improve technical efficiency of the farm. A study by Deininger and Jin (2005) suggests that land rental markets are more effective than administrative reallocation in reallocating land to those with lower endowments and have a bigger productivity-enhancing effect. Hence, even though administrative land reallocation partially substitutes for the market mechanism and contributes to the improvement of farm technical efficiency, the development of the land rental market needs to be encouraged in achieving allocative efficiency. This prescription is also reinforced by the results for Zhejiang, where land rental markets and other related factor markets are already relatively well functioning. Under these circumstances, the administrative land reallocation process exerts a negative effect on the technical efficiency of farmers.

In order to measure the impact of land fragmentation, we introduce six variables for the share of plots with different sizes (see Table 2), using the share of plots with size smaller than 0.5 mu as a reference. Even though most of the coefficients are not significant, the prevailing negative signs present information that the larger the plot size, the more efficient the production. Thus, land fragmentation could be a hindrance to the improvement of technical efficiency. A dummy variable, which indicates whether any of the household members is a township or village cadre, is used here as a proxy for the management capability of farm households and its effect is not significant in all three provinces. The share of rural laborers with primary, secondary, and high school education and above (share of illiterate rural laborers as reference) all have negative signs in Hubei and Yunnan. Additionally, the higher the level of education, the larger the efficiency scores. The coefficient of share of labor with skill training is significantly positive only in Hubei. This could be explained that skill training increases the chance of finding a job in an urban area; hence, it is a disincentive to working in agricultural production.

5. Conclusion

Due to China's economic reforms, farmers face an increased risk of land reallocation and adjustment. This raises questions about the impact of land reallocation on farm productivity and efficiency. An in-depth understanding of what determines land reallocation and how farm production and efficiency are affected by the incidence of land reallocation could help policy makers introduce more targeted rural development policies. Based on a panel data set from 1995 to 2002 for rural households in Zhejiang, Hubei, and Yunnan provinces, the descriptive statistics show that frequent land reallocation is still common in some villages. Our stage 1 model results indicate that the development of the land rental market is essential because it can serve as a substitute for administrative land reallocation in optimizing the distribution of land resources. Demographic change does affect land reallocation in some regions. Even though land allocation is officially intended to guarantee equal access to land for all farmers, the negative effects on tenure security are obvious, especially against the background of the ongoing rural–urban migration.

The results from the stochastic frontier production function show that land reallocation does have effects on technical efficiency. The different signs for different provinces also imply that the impact of land reallocation on technical efficiency is an empirical issue. Because of the possibility that administrative land reallocation can partially serve as a substitute for missing or badly functioning land rental markets, land reallocation could facilitate the process of improving land access for more successful farmers; hence, it could improve technical efficiency of agricultural production. But at the same time, in regions where land rental markets and other related factor markets are already relatively well developed, administrative land reallocation seems to distort the market mechanism, undermining market signals, and thus seems to decrease technical efficiency. In addition, our study also indicates that land fragmentation could be a major hindrance to the improvement of technical efficiency while highlighting the important role of a higher level of education, which exerts positive effects on the technical efficiency.

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