Land rental, off-farm employment and technical efficiency of farm households in Jiangxi Province, China

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Abstract

Land rental market development and off-farm employment have important implications for agricultural production. This study examined the effects of land rental market participation, the resulting land tenure contracts, and off-farm employment on the technical efficiency in rice production in rural China, using the one-step stochastic frontier approach. Data from a survey held at household and plot level in three villages in north-east Jiangxi Province were used to estimate the stochastic frontier model. We found that the mean technical efficiency of rice production in north-east Jiangxi Province ranged from 0.36 to 0.97, with an average of 0.82. The determinants of technical efficiency show that households that rented land achieved higher technical efficiency than households that did not rent land. Rice production on rented plots was technically as efficient as on contracted plots. Additionally, participation in migration did not have an effect on technical efficiency.

Additional keywords: migration, stochastic frontier approach, technical efficiency

Introduction

Economic reforms initiated in the late 1970s have drastically affected the development of the Chinese agricultural sector. In particular, the switch from collective farming to the household responsibility system (HRS) has resulted in an important change in the land tenure system, where farmland is still owned by the village collective but production and management of farmland are entrusted to individual households through long-term contracts. The implementation of this new land tenure system brought about a rapid growth of agricultural productivity in the early reform years (1979–1984) because of the institutional innovation, which links farm households' income closely with their own performance (McMillan *et al.*, 1989; Fan, 1991; Lin, 1992). The rising agricultural productivity decreased the demand for labour in agriculture, providing a strong incentive for rural labourers to shift to off-farm employment. Since the early 1980s an off-farm economy has emerged, consisting of jobs in Township and Village Enterprises (TVEs), in urban centres and more recently private enterprises, and has accelerated its growth since 1995 (De Brauw *et al.*, 2002).

Farmland in China is legally owned by the village collective. Under the HRS, land use rights have been equally assigned by the village collective to individual farm households for a period of up to 15 years, depending on family size, labour force, or a combination of both. Land transfers were initially not allowed, because policy makers believed that land transfers would lead to a concentration of land in the hands of a few households, leaving most households landless. Instead, frequent administrative reallocations of land by the village collective have been used to correct for demographic changes. All of these have resulted in insecure land use rights, which are often considered to reduce farm households' incentive to carry out long-term land investment. To solve these problems, the Chinese government has permitted land rentals since the mid-1980s and allowed land use rights to be extended for another 30 years in 1993. Since then a rural land rental market has emerged.

Theoretically, a land rental market can enhance allocative efficiency and agricultural productivity by equalizing the marginal product of land among households with different land–labour endowments and by facilitating transfers of land from less productive households to more productive ones (Faruqee & Carey, 1997; Carter & Olinto, 1998; Carter & Yao, 1999; 2002; Deininger & Feder, 2001; Deininger, 2003; Deininger & Zegarra, 2003; Deininger *et al.*, 2003; Deininger & Jin, 2005; Yao, 2007). However, in present-day China land rental arrangements are generally informal, short term, and between households living in the same village. Plots rented from other households are therefore subject to tenure insecurity, which may discourage long-term land investment and reduce agricultural productivity.

The effect of off-farm employment on agricultural production is ambiguous. Off-farm employment reduces the labour available for agricultural production, especially if hiring agricultural labour incurs transaction costs and if hired labour is not as efficient as family labour. Off-farm employment also enables households to increase their incomes, to overcome credit and insurance constraints and to increase their use of industrial inputs (Rozelle *et al.*, 1999a; Taylor *et al.*, 2003). In addition, the reduction in food consumption resulting from household members working off-farm (e.g., those who migrate) may have an impact on agricultural production decisions if household production and consumption decisions are non-separable (Burger, 1994; Wouterse, 2006).

Most of the literature concerning land and labour market development and agricultural production in rural China has focused either on the land (Lohmar *et al.*, 2001; Carter & Yao, 2002;) or on the labour market (Wu & Meng, 1997a, b; Rozelle *et al.*, 1999a; Taylor *et al.*, 2003). Previous studies on the effect of land tenure contracts on agricultural production have focused on South Asia (Shaban, 1987; Otsuka & Hayami, 1988; Binswanger *et al.*, 1995) and Africa (Gavian & Fafchamps, 1996; Gavian & Ehui, 1999; Ahmed *et al.*, 2000; Place & Otsuka, 2000; Benin *et al.*, 2005; Pender & Fafchamps, 2006). The focus of these studies has been on comparing the relative efficiency of owner-operated, rented, or sharecropped plots. Many studies found an efficiency loss of sharecropped land relative to owner-operated land.

Empirical evidence shows that agricultural factor markets in rural China, particularly land and labour, face many institutional obstacles and remain underdeveloped (Carter & Yao, 2002; Bowlus & Sicular, 2003). Faced with land and labour market imperfections, household production and consumption decisions may be non-separable and household may make simultaneous decisions on land and labour market participation and agricultural production. To our knowledge there has been no research that has analysed the effect of land and labour market participation on agricultural production in rural China. The objective of this study was therefore to estimate the technical efficiency in rice production and examine the effect of land rental market participation, the resulting land tenure contracts, and off-farm employment on technical efficiency in rural China.

This study used the stochastic frontier approach. It differs in several ways from previous technical efficiency analyses in China (Tan, 2005; Chen *et al.*, 2006). First, the input and output data were collected at plot level. This was expected to yield more accurate technical efficiency scores, because plot characteristics (e.g., soil quality) are different across plots. Second, only rice plots were included in the sample, as production technologies and technical efficiency may differ across different crop species. Third, a one-step stochastic frontier approach was applied to overcome the misspecification of the efficiency levels (Kumbhakar *et al.*, 1991; Coelli *et al.*, 1998).

The remainder of this paper is organized as follows. The next chapter presents the empirical stochastic frontier model and the data used in this study. Then the estimation results are presented. The paper concludes with summarizing the main findings and finally drawing some policy implications.

The stochastic frontier model

Theoretical model

A stochastic frontier production model (Aigner *et al.*, 1977; Battese & Corra, 1977; Meeusen & Van De Broeck, 1977) is applied to estimate the technical efficiency scores for different plots, as measurement errors and weather-related random disturbances are substantial in analysing plot level data (Coelli, 1995). This means that we estimate a production function with an error term consisting of two components, one to account for pure random effects and another to account for technical inefficiency (TIE). This production function can be expressed as follows:

$$Y_i = x_i\beta + (v_i - u_i) \qquad (1)$$

where Y_i is the output of plot i (i = 1, ..., n), x_i is a vector of inputs of the ith plot, β is a row vector of an unknown parameter to be estimated, v_i is the random error of plot i, which is assumed to be independently and identically distributed (iid) as $N(0, \sigma_V^2)$, and independent of the u_i, a non-negative random error, which is assumed to account for technical inefficiency (TIE) and often assumed to be iid and have a half normal

$N^+(0, \sigma_u^2)$ distribution. It varies between 0 and 1.

Technical efficiency is defined as $TE_i = \exp(-u_i)$. The technical efficiency determinants are expressed as:

$$TE_i = z_i \delta \qquad (2)$$

where z_i is a vector of factors that may determine the technical efficiency and does not contain any variables in x_i; δ is a vector of unknown parameters to be estimated.

Parameters β, δ, σ_v, σ_u, and TE are estimated by the maximum likelihood method.

Data

The data used in this paper were collected in three villages in north-east Jiangxi Province described in Feng & Heerink (2008). Farm household level data were collected for the year 2000. Plot level data, however, were not collected then. Out of the 329 households interviewed in 2000 and 2001, 52 households were randomly selected. The analysis here is limited to households that rented land. This is because it is impossible to ask households about their rice production on leased plots. Plot level agricultural production data were collected in January 2003 for the entire year 2002. In total 215 rice plots were surveyed: 56 in Banqiao, 74 in Shangzhu and 85 in Gangyan (Feng & Heerink, 2008). This is because rice is the dominant crop in the research area. Collected information includes tenure status of the plots, inputs and output of each plot, plot characteristics, and soil quality.

Model specification and estimation methods

Specification of the frontier production function

First, a frontier production function was specified. In frontier production analysis generally two types of production functions are used: the Cobb-Douglas and the translog function. The relatively large number of inputs that we distinguished in this study greatly complicates the application of a translog function. For the analysis of the data we therefore chose the Cobb-Douglas production function.

Agricultural production depends in general on land area, labour, seed, inorganic fertilizers, herbicides and pesticides, animal and mechanical traction, and soil quality. The descriptive statistics of the variables used in our stochastic frontier production function estimation, subdivided by land market regimes and tenure status of the plot, are presented in Table 1.

Households in the surveyed area grow either one or two rice crops a year. The yields vary among varieties. For our study the yields have been aggregated and measured in monetary units. The average rice output was 884.12 yuan per plot, or 297.73 yuan per mu and the average plot area per household used for rice production was about 2.92 mu (Table 1). Labour used for rice production was measured in man-days per plot. Households work on average around 97.04 days on each plot, or 40 days on each mu of land. Seed, inorganic fertilizers, herbicides and pesticides, and animal and mechanical traction used for rice production were measured in monetary units. All inputs in

Table 1. Descriptive statistics of the variables used in the stochastic frontier production function estimation, in relation to land rental market regime and tenure status of the plots.

Item	Unit/ dummy values	Type of household			
		Renting		Self-sufficient	All plots
		Contracted	Rented	Contracted	
		(n = 60)	(n = 43)	(n = 112)	(n = 215)
		[Mean (standard deviation)]			
Dependent variable					
Gross value of rice output	yuan [1]	948.03 (719.56)	1341.28 (1930.26)	674.36 (739.02)	884.12 (1106.09)
Explanatory variables					
Area planted	mu [2]	2.97 (2.20)	3.88 (5.03)	2.53 (2.41)	2.92 (3.10)
Labour used	days	97.58 (69.97)	115.35 (108.90)	89.73 (58.53)	97.04 (74.49)
Seed	yuan	25.26 (25.57)	28.77 (43.10)	26.16 (23.13)	26.43 (28.70)
Inorganic fertilizers	yuan	163.95 (157.70)	213.89 (271.79)	112.14 (143.74)	146.95 (183.54)
Herbicides & pesticides	yuan	31.80 (27.08)	44.25 (71.37)	26.06 (24.62)	31.30 (39.55)
Oxen & tractors used	yuan	73.16 (57.87)	92.35 (113.36)	69.47 (97.67)	75.08 (92.04)
Topsoil depth	cm	16.73 (4.54)	17.80 (3.86)	16.36 (3.74)	16.75 (4.02)
Banqiao dummy	0 or 1	0.22 (0.42)	0.12 (0.32)	0.34 (0.48)	0.26 (0.44)
Shangzhu dummy	0 or 1	0.15 (0.36)	0.07 (0.26)	0.55 (0.50)	0.34 (0.48)

[1] Based on price level of 2002. Since the autumn of 2003 prices have risen considerably.
[2] 1 mu = 1/15 ha.

the Cobb-Douglas production function were expected to have a positive effect on rice production, except for herbicides and pesticides. Their effects on land productivity depend on whether they are applied for the prevention or control of weeds and pests.

In addition to the traditional inputs, rice production is influenced by the quality of the soil. In this study, topsoil depth was used as soil quality indicator. Topsoil depth was estimated by soil scientists, and measured in centimetres. It was expected that rice production is positively correlated with topsoil depth. Two dummy variables for the Banqiao and Shangzhu villages were included to capture the variation in other factors that systematically differ between the villages. It was assumed that the production frontier may shift by village.

Specification of the technical efficiency function

Technical efficiency is likely to be affected by factors that are associated with farm management practices (Forsund *et al.*, 1980), including indicators of plot tenure security, plot characteristics, farm characteristics, household characteristics, household participation in the land rental market and off-farm employment. Descriptive statistics of the variables used in technical efficiency determinant estimation, subdivided by land market regimes and tenure status of the plot are listed in Table 2.

Plot tenure security is represented by the tenure status of the plot. Two plot tenure

Table 2. Descriptive statistics of the variables used in the technical efficiency determinant estimation, in relation to land market regime and tenure status of the plots.

Item	Unit/ dummy values	Type of household			
		Renting		Self-sufficient	All plots
		Contracted	Rented	Contracted	
		(n = 60)	(n = 43)	(n = 112)	(n = 215)
		[Mean (standard deviation)][1]			
Dependent variable					
Technical efficiency		0.87 (0.10)	0.89 (0.10)	0.77 (0.15)	0.82 (0.14)
Explanatory variables					
Rented plot (A)	0 or 1	0.00 (0.00)	1.00 (0.00)	0.00 (0.00)	0.20 (0.40)
Household renting land (B) [2]		0.72 (0.26)	0.77 (0.24)	0.14 (0.20)	0.43 (0.38)
A × B interaction		**0.00** (0.00)	**0.77** (0.24)	0.00 (0.00)	0.15 (0.33)
Participate in migration	0 or 1	0.53 (0.50)	0.40 (0.49)	0.54 (0.50)	0.51 (0.50)
Distance from home	minutes	**11.76** (8.22)	**17.92** (13.63)	11.23 (10.29)	12.71 (10.81)
Household size	persons	5.60 (1.44)	5.40 (1.43)	4.79 (1.91)	5.13 (1.73)
No. of dependants	persons	1.98 (1.32)	2.26 (1.42)	1.39 (1.02)	1.73 (1.24)
No. of durable assets		7.08 (1.41)	7.30 (1.32)	6.46 (1.67)	6.80 (1.57)
Total number of cattle		1.17 (1.76)	2.16 (3.22)	0.67 (0.47)	1.11 (1.82)
Age household head	years	51.15 (13.11)	46.84 (13.29)	45.46 (9.81)	47.33 (11.75)
Education household head	years	3.78 (2.49)	4.37 (2.61)	5.24 (2.86)	4.66 (2.78)
Female-male adult ratio		1.12 (0.67)	1.14 (0.57)	1.09 (0.69)	1.11 (0.66)
No. of plots		4.33 (1.74)	4.30 (1.32)	4.98 (1.96)	4.67 (1.81)
Irrigated land per adult	mu [3]	2.39 (1.65)	3.25 (2.10)	2.06 (1.38)	2.39 (1.68)

[1] Means in the same row, printed in **bold** are statistically different ($P < 0.005$).

[2] Household renting decisions are possibilities predicted with a probit model (see Appendix 2).

[3] 1 mu = 1/15 ha.

statuses were distinguished: contracted and rented. Contracted plots are plots that are distributed directly by the village collective. Rented plots are plots rented from other households. Of all the plots in the analysis, 172 plots were contracted, and 43 plots rented. A dummy variable, which equals 1 when the plot was rented and 0 when the plot was contracted, was used to indicate the tenure status of the plot. Normally, the land rental arrangements are verbal and of short duration. Rented plots are therefore less secure than contracted plots and expected to be negatively correlated with technical efficiency. Plot characteristics are represented by the distance between plot and home. This distance is measured in minutes travelling time. A longer travelling time raises the cost of carrying inputs from home. On distant plots, farm households tend to apply inputs in larger quantities and at lower frequencies. Distance is thus expected to be negatively correlated with technical efficiency.

Farm characteristics were represented by the number of cattle in a household at the end of the previous year, age and education of the head of the household, the household land endowment, and the number of plots that a household had. In the research area, cattle are very important draft animals for small-scale households. The number of cattle in a household is expected to have a positive impact on technical efficiency, as the availability of cattle is associated with the timeliness of land preparation in rice production. Age of the household head was used as a proxy for the family's farming experience. The effect of age on technical efficiency is ambiguous, depending on whether older farmers are more experienced or more likely to stick to farming traditions and less likely to adopt new technologies. Education of the household head was used as a proxy for the management skills of a family. Technical efficiency is expected to increase with education as education increases the household's ability to utilize existing technologies and make farm management decisions (Battese & Coelli, 1995). The household land endowment was represented by the area of irrigated land contracted per adult. The household land endowment is expected to have a positive impact on technical efficiency, because a larger land endowment implies the economy of scale. The square of this variable was added to the equation to capture the possible non-linearities in its impact. The number of plots in a household is an indicator of land fragmentation, which can have either negative or positive effects on technical efficiency (Tan, 2005). On the one hand, a larger number of plots needs more labour (Nguyen *et al.*, 1996) and may be more difficult to manage. On the other hand, it enables households to optimize their labour allocation over different crop species and seasons, especially if there is no market for agricultural labour (Fenoaltea, 1976).

Household characteristics were represented by the number of durable assets in a household, household size, number of dependants in a household, and the ratio female–male adults. Households with more durable assets are expected to face fewer obstacles in agricultural production, as they have more resources available for paying fixed costs and for obtaining the information needed to adopt new technologies. So the number of durable assets in a household is expected to improve technical efficiency. Household size, number of dependants in a household and the ratio female–male adults are expected to affect technical efficiency through their effects on the household time endowment. Larger households and those with fewer dependants are expected to be technically more efficient since they have more labourers available to implement farm management practices in time. The ratio female–male adults is used to test for differences between females and males in physical strength or other differences in agricultural production. Males are more likely to deal with farming operations that require much physical strength. It is therefore expected that a higher value of this ratio will lead to a low technical efficiency.

As mentioned previously, households renting land are expected to achieve a higher technical efficiency because a developed land rental market enables the transfer of land from less efficient, to more efficient households. Following Pender & Fafchamps (2006), the interaction between households renting land and the rented plot dummy was included in the model to test for differences in technical efficiency on contracted and rented plots for households that rent land. This is because it is not possible to determine these differences from the average effect of either the tenure status of the plot or households renting land. Off-farm employment affects technical efficiency in three ways. The first one is through the lost-labour effect. Off-farm employment can be expected to reduce technical efficiency, especially if hiring agricultural labour incurs transaction costs and hired labour is not as efficient as family labour. The second one is through the income effect. Off-farm employment is expected to increase household incomes, and thereby facilitate the use of material inputs and improve technical efficiency (Rozelle *et al.*, 1999a; Taylor *et al.*, 2003). The third one is through the reduced-consumption effect. Household members working off-farm (e.g., off-farm employment by migrated members) means less food consumption and therefore reduces agricultural production if household production and consumption decisions are non-separable (Burger, 1994; Wouterse, 2006). So the effect of off-farm employment on technical efficiency is ambiguous.

Estimation method

The stochastic frontier model can be estimated using one-step or two-step approaches. In the two-step procedure, the frontier production function and the firm's efficiency levels (*TE*) are estimated first (Equation 1), ignoring a set of variables (*z*) that affect technical efficiency. In the second step, efficiency levels (*TE*) are regressed against the variables (*z*) to see how efficiency levels vary with these variables (Equation 2). However, the two-stage procedure has long been recognized to yield biased results because the model estimated at the first step is misspecified (Coelli *et al.*, 1998; Wang & Schmidt, 2002). A one-step procedure is suggested to solve the bias problem, in which the relationship between technical efficiency and the variables is imposed directly in estimating the frontier production function and the firm's efficiency levels (Kumbhakar *et al.*, 1991; Wang & Schmidt, 2002). The maximum likelihood estimates were computed using the statistical package STATA 9.

All explanatory variables in Equation 2 should be exogenous. However, households' participation in land renting as well as off-farm employment may be endogenous as they depend on household characteristics, farm characteristics, household land and labour endowments, institutional factors, and market rent, wage, and other prices [see Feng & Heerink (2008) for details]. As mentioned earlier, data on household participation in off-farm employment were collected for the year 2000, whereas data on household participation in land renting and plot level agricultural production were collected for the year 2002. Household participation in off-farm employment is therefore treated as exogenous, and represented by households' participation in migration in the year 2000. Decisions on land renting were made in the year 2002 and may therefore be considered endogenous. Inclusion of endogenous variables in the estimation may result in biased estimates. Instrumental variables are used to address this endogeneity problem. First a probit model was used to estimate land renting at the farm household level, and to predict the probability of households' participation in land renting. The predicted probability was then used as an instrument for the actual participation in the land rental market in maximum likelihood estimates.

Estimation results

Determinants of renting land

The dependent variable for renting land is a binary variable, which equals 1 if the household rented land in year 2002, and 0 otherwise. The explanatory variables and their expected effects were specified and discussed in detail in Feng & Heerink (2008). The statistics of the explanatory variables, grouped by households' land market participation decisions, are summarized in Appendix 1.

Of all the households in the three villages, 19 households rented irrigated land in 2002. The results of the probit model are presented in Appendix 2. A U-shaped relationship was found between land availability and land renting decisions. This finding confirms the result for the initial 329 households analysed by Feng (2006), i.e., that households with both low and high land availability are more likely to rent additional land. A possible explanation is that households with relatively large land availability tend to specialize in agricultural production and therefore want to enlarge their farm size. The turning point was 2.35 mu.

The land transfer rights indicator positively affected land-renting decisions. This confirms the hypothesis that households that enjoy more land transfer rights tend to rent additional land. Households' migration experience did not affect land renting. The results for the two village dummy variables indicate that there were significant differences between the villages in market wage, land rent and other factors affecting renting land. Households in Banqiao and Shangzhu villages were less likely to rent additional land than households in Gangyan village.

The stochastic frontier production function and technical efficiency scores

The results of the stochastic frontier production function are presented in the upper part of Table 3. As expected, output responded positively to land, labour and inorganic fertilizers. The elasticities of output with respect to land, labour and inorganic fertilizers were 0.93, 0.06 and 0.06, respectively, indicating the importance of land as a scarce resource for rice production in China. Surprisingly, output responses to seed and oxen and tractor were negative and statistically significant. The sum of the elasticities, excluding soil quality and the two village dummies, was 0.94. A test for constant returns to scale is rejected for rice production. The quality of the plot, represented by topsoil depth, is an important determinant of rice production. The elasticity with respect to topsoil depth was 0.18, suggesting the importance of improving soil quality for rice production. The results for the two village dummy variables indicate that plots in Banqiao and Shangzhu village achieve a lower rice output than the plots in Gangyan village.

Technical efficiency scores obtained from the stochastic frontier production function are summarized in Table 2. The average technical efficiency score for our sample was 0.82, which is consistent with an earlier study conducted in the same villages (Tan, 2005). This indicates that on average 82% of the potential output can be obtained by using the current mixture of production inputs. It also reveals the challenge and potential for improving rice production in north-east Jiangxi Province. The technical

Table 3. Frontier production functions and technical efficiency estimates.

Independent variable		Coefficient [1]	z-score
Stochastic frontier function			
ln area planted (mu) [2]		0.92***	17.57
ln labour used (days)		0.08**	2.25
ln seed used (yuan)		−0.05***	−2.98
ln inorganic fertilizer used (yuan)		0.06*	1.70
ln herbicides and pesticides used (yuan)		0.001	0.05
ln oxen and tractor used (yuan)		−0.07***	−3.10
ln topsoil depth (cm)		0.18***	2.79
Banqiao dummy		−0.11***	−2.71
Shangzhu dummy		−0.17**	−2.40
Intercept		5.27***	19.01
Factors determining technical efficiency			
Type of tenure			
Rented plot [3] (A)		−0.48	−0.39
Land rental market participation and off-farm employment			
Household renting land [3] (B)		1.78**	2.10
Interaction A × B		0.07	0.04
Participate in migration (1 = yes)		−0.38	−0.89
Other variables			
ln distance from home (minutes)		0.21	1.11
ln household size (persons)		2.15**	2.09
ln number of dependants (persons)		−1.49**	−2.30
ln number of durable assets		0.10	0.21
ln total number of cattle		−0.88	−1.59
ln age of household head (years)		−0.70	−0.65
ln education of household head (years)		−0.20	−0.71
ln ratio female / male adults		−0.99**	−1.65
ln number of plots		−2.11***	−3.49
ln irrigated land per adult (mu)		1.23**	2.22
ln (irrigated land per adult) squared		0.78	1.29
Intercept		5.65	1.19
σ_v		0.14***	7.50
Number of observations	215		
log likelihood	35.41		
Wald χ^2 (8)	3809.98		
$P > \chi^2$	0.00		

[1] Level of statistical significance. *: $P = 0.10$; **: $P = 0.05$; ***: $P = 0.01$.

[2] 1 mu = 1/15 ha.

[3] Renting decision is predicted probability estimated by a probit model (see Appendix 2). A test for multicolinearity of variables included showed that the mean variance inflation factor (VIF) was 4.72. For area planted, type of tenure and the interaction term, VIF was 12.14, 11.01 and 12.18, respectively. However, this multicolinearity is inevitable since these variables must be included in the analysis. An attempt was made to normalize plot output and inputs by plot area in order to solve the multicolinearity detected, but the results were not importantly different.

efficiency estimates ranged from 0.36 to 0.97. Of all the plots in our sample, around 35% had technical efficiency scores below 0.82. This suggests that substantial gains in rice production can still be obtained by improving farm management practices under the existing technologies.

Determinants of technical efficiency

The results for the determinants of technical efficiency are presented in the lower part of Table 3. The technical efficiency did not differ significantly between rented plots and contracted plots, indicating that rented plots are technically as efficient as contracted plots. A possible explanation is that land investments are less on rented plots due to insecure tenure, but that more variable inputs are used because households renting land tend to maximize short-term agricultural profits on these plots. Households renting land achieved a higher technical efficiency. This finding confirms the result of earlier research by Lohmar *et al*. (2001) and Feng (2006), i.e., that land rental markets could facilitate the transfer of land from less productive households to more productive households. For households that rent land, no difference was found in technical efficiency between rented plots and contracted plots. This is shown by the insignificance of the sum of the coefficients for rented plots and the interaction between household renting land and rented plot (0.41; $P = 0.63$). This finding indicates that there is no efficiency loss on rented plots relative to contracted plots (Shaban, 1987; Pender & Fafchamps, 2006). Participation in migration did not have an effect on technical efficiency.

Household size positively affected technical efficiency, whereas the number of dependants had a negative effect, indicating that larger households and households with fewer dependants were technically more efficient. An explanation for this may be that these households consume more food and therefore strive for a higher output. In addition, these households have more labour endowment available for timely farm management practices. As expected, the ratio female–male adults had a negative effect on technical efficiency. Surprisingly, land availability positively affected technical efficiency, indicating either an increasing returns to scale or imperfections in factor markets. The number of plots in a household negatively affected technical efficiency, which indicates that land fragmentation reduces technical efficiency.

Conclusions

Land rental market development and off-farm employment have important implications for agricultural production. Applying household and plot level data, this study investigated the technical efficiency in rice production and examined the effect of land rental market participation, the resulting land tenure contracts, and off-farm employment on technical efficiency in three villages in north-east Jiangxi Province. A one-step stochastic frontier approach was applied to overcome the misspecification of the efficiency levels (Kumbhakar *et al*., 1991; Coelli *et al*., 1998).

We found that the mean technical efficiency of rice production in north-east Jiangxi

Province was 0.82, suggesting that there is an 18% scope for increasing rice production under the existing technological conditions. The technical efficiency estimates ranged from 0.36 to 0.97. Results from the determinants of technical efficiency show that rented plots are technically as efficient as contracted plots. This finding confirms that there is no efficiency loss on rented plots relative to contracted plots. Households renting land achieve a higher technical efficiency, indicating that the development of land rental markets allows land to be transferred to those that are more capable of earning a high return from agricultural production. The results therefore suggest that policies to stimulate the development of land rental markets could contribute significantly to agricultural production in rural China.

The findings also show that participation in migration does not have an effect on technical efficiency. A possible explanation of this finding is that agricultural production in the research area is characterized by a small farm size and a large labour surplus and that the remittances sent by migrants are mainly used for non-agricultural purposes, such as building houses and marriage. Although off-farm employment does not directly affect agricultural production, policies aimed at improving access to off-farm employment opportunities may at least improve labour productivity in agricultural production and household incomes in rural China.

Our analysis was affected by a number of limitations. First, to facilitate the use of the one-step stochastic frontier approach some strong assumptions had to be made about the standard errors, such as homoskedasticity, and independence of different plots managed by the same household. The statistical issues of testing the validity of these strong assumptions need to be addressed in future research. Second, the analysis focused on the plot and not on the household. By focusing on plots, this study ignored implicitly the heterogeneity between different households. However, this is inevitable in this kind of analysis (Ahmed *et al.*, 2002).

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Appendix 1

Descriptive statistics of the variables used in land rental market participation

Item	Unit/ dummy values	Type of household		
		Self-sufficient in land	Renting land	All households
		(n = 33)	(n = 19)	(n = 52)
Household size	persons	4.70 (1.86) [1]	5.47 (1.50)	4.98 (1.77)
No. of dependants	persons	1.33 (0.99)	1.79 (1.32)	1.50 (1.13)
No. of durable assets		6.52 (1.82)	7.11 (1.41)	6.73 (1.69)
Total number of cattle		0.67 (0.48)	1.32 (2.19)	0.90 (1.39)
Age of household head	years	**45.39** (9.81) [2]	**51.84** (12.62)	47.75 (11.24)
Education of household head	years	**5.27** (2.83)	**3.84** (2.50)	4.75 (2.78)
Female-male adult ratio		1.13 (0.74)	1.23 (0.79)	1.17 (0.75)
Irrigated land per adult	mu [3]	1.88 (1.26)	2.24 (1.76)	2.01 (1.46)
Possession land contract	0 or 1	0.15 (0.36)	0.21 (0.42)	0.17 (0.38)
Land transfer rights		**0.56** (0.13)	**0.64** (0.13)	0.59 (0.13)
Participate in migration	0 or 1	0.52 (0.51)	0.53 (0.51)	0.52 (0.50)
Banqiao dummy	0 or 1	0.33 (0.48)	0.21 (0.42)	0.29 (0.46)
Shangzhu dummy	0 or 1	**0.55** (0.51)	**0.16** (0.38)	0.40 (0.50)

[1] Means with standard deviation in parentheses.

[2] Means in the same row, printed in **bold** are statistically different ($P < 0.10$).

[3] 1 mu = 1/15 ha.

Appendix 2

Determinants of land renting probit model

Independent variable	Estimated coefficient [1] (z-score)
ln household size (persons)	1.46 (0.81)
ln number of dependants (persons)	–0.39 (–0.35)
ln number of durable assets	0.45 (0.66)
ln total number of cattle	1.34 (1.53)
ln age of household head (years)	–15.61 (–0.35)
ln (age of household head)^2	2.35 (0.41)
ln education of household head (years)	0.20 (0.35)
ln ratio of female / male adults	–0.24 (–0.24)
ln irrigated land per adult (mu)	–1.41 (–2.81)***
ln (irrigated land per adult)^2	0.83 (2.11)**
Possession land contract (1 = yes)	0.64 (1.11)
Land transfer rights	3.39 (1.82)*
Participate in migration (1 = yes)	–0.67 (–1.10)
Banqiao dummy	–1.92 (–2.22)**
Shangzhu dummy	–2.79 (–3.52)***
Intercept	20.88 (0.25)
Number of observations	52
log likelihood	–16.85
Pseudo R^2	0.51
Correctly specified (%)	88.46

[1] Standard errors are robust to heteroskedasticity. Statistical significance: * = $P < 0.10$; ** = $P < 0.05$; *** = $P < 0.01$. Test for multicolinearity among variables shows that mean variance inflation factor (VIF) is 2.07, and VIF for each individual variable is lower than 10.