Is the Small-sized Rural Household More Efficient?

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Abstract: Study on the Inverse Relationship between farm's efficiency and farm size is always a hot topic in the agricultural economics, but the farm's efficiency is measured by land productivity usually. So the Inverse Relationship (IR) measures the relationship between land productivity and farm's scale actually. Using the farm-level micro panel data from Hubei province in China in 1999-2003, the paper, from the multi-perspectives of farm's land productivity, labor productivity, profit rate of cost, total factor productivity and technical efficiency, discusses the relationship between farm's efficiency and farm size, and analyzes the effects of rural household endowments on the farm's efficiency. The empirical conclusions are as follows: An overall look in a broader vision should be given to the hypothesis of the Inverse Relationship. Whether the small-sized farm, compared to large-sized one, enjoys the efficiency's comparative advantages depends on the top-priority policy goals.
Key words: Farm; Farm size; Efficiency; Inverse relationship

1 Introduction

Since Sen (1962) found that there is Inverse Relationship (IR) between the rural household scale and its efficiency in Indian agriculture, the traditional view that the obvious scale of economy existed because of the indivisibility of some agricultural resources has been vigorously challenged, and moreover, the existence of IR between the rural household scale and its efficiency and how to explain it reasonably have drawn many researchers' attention.However, the studies about the IR and the controversy about how to explain it are still on and no agreement has been reached for a long time. In the first place, some researchers doubt the existence of IR between the rural household scale and its efficiency. For instance, Nehring *et al.* (1989), Bravo-Ureta and Rieger (1990), and Kumbhakar (1993) demonstrated that the relationship between the two is positive. While Carter and Wiebe (1990), Benjamin (1995) and Lamb (2003) hold that the relationship between the scale and efficiency is probably non-linear. And Bagi (1982), Bagi and Huang (1983), Bravo-Ureta (1986), Moussa and Jones (1991) show that the two, cannot establish notable connect statistically. The existing literatures about the Inverse Relationship mainly provide these explanations: (1) the factor market is not complete, which includes the differences of land, labor force and capital market between large-scale farmers and small-scale farmers, especially the role of labor market; (2) the differences in the field quality and utilization degree; (3) rural household' heterogeneity; (4) Chayanov's peasant self-exploitation theory; (5) the rural households are in face of the differences in the transaction costs, supervision costs and motivate mechanism in the household's inner organization.

The statement whether the developing countries have "Inverse Relationship" in the agricultural industry has strong political implication, for it relates to specific development strategies for agriculture, land reform, rural equity and the future of small peasant economy based on household management. And it is particularly important for China. With regard to the resource endowments, China is a typical developing country with vast population and limited farmland, and rich rural laborers. Essentially, the household contract responsibility system (HRS), enforced after the collapse of collectivization system in 1978, is an agricultural strategy of small rural households based on land-sharing. Due to the historical wrong population policy, specific resource endowments and typical dual economic structure, small-scale family agriculture will continue to be a prominent feature of China's future agriculture in a fairly long period of time. But China's agriculture nowadays is also facing the historic opportunity where three major changes, i.e. the large-scale of non-agricultural employment, slower population growth and adjustment of agricultural production structure co-existed. In particular, the need for farmland transfer to reach larger scale is greater and greater in some developed provinces. We found that there are few empirical studies for Chinese cases in the existing literatures. If small-scale rural household, compared with large-scale rural household, does enjoy comparative advantages in the efficiency, it has significant meaning or re-thinking necessity for China's future agricultural and land policy.

However, after summarized the existing "IR" literatures, we have found that the agricultural efficiency is often measured by "per unit area yield" or "value of per unit area yield", namely by the land productivity when the existed studies refer the inverse relationship (IR) between the rural household scale and agricultural efficiency. It is probably because most developing countries need to give priority to their basic food safety and put the land productivity in the first achieving goal. Therefore, great emphasis has lain on per unit area yield or land productivity. But it must clearly point out that per unit area yield is an indicator of Single Factor Productivity (SFP), and it cannot reflect the whole agricultural production process comprehensively. While agricultural efficiency is a multi-dimensional comprehensive concept in the production process, including labor productivity, profit ratio of cost, Total Factor Productivity (TFP) which fully reflects the comprehensive production status and Technical Efficiency (TE) which fully reflects the utilization of related technology, *etc.* Moreover, different efficiency indicators have different policy implications. For instance, labor productivity is highly related to farmers' income. Thus, in a broader efficiency indicator view, do the small-scale rural households enjoy the comparative advantages toward large-scale rural household? Or does the inverse relationship (IR) still exist?

Therefore, what the paper pays attention is to fully and comprehensively investigate the relationship between the agricultural efficiency and the rural household's scale. Aside from continuing to study the relationship between land productivity and rural household's scale, the paper lays emphasis on the relationship between labor productivity, profit ratio of cost, Total Factor Productivity, Technical Efficiency and the rural household's scale (measured by "cultivated land area"), to fully test the empirical hypothesis that whether the small-scale rural household does enjoy comparative advantages toward large-scale rural household in the efficiency. Besides household's scale, there are other household's characteristic variables that exert an effect on household's efficiency and must be classified and controlled. These characteristic factors can be summed up into Household Endowment (HE) of a household in the paper, including education, technical training and social networks *etc.* Meanwhile, analysis of these micro characteristic factors in the household endowment that reflect household's heterogeneity is also included in the paper.

2 Variables, Data and Research Method

2.1 Research method

In the traditional studies of IR, classical equation (1) is employed mostly for OLS estimation:

$$Efficiency_i^f = C + \beta \ln OP_i + \varepsilon_i \tag{1}$$

$Efficiency$ is the land productivity indicator of the corresponding rural household, OP is the actual land area, ε is classical random noise term. If $\beta < 0$ and significance, then it can determine the inverse relationship (IR) exists, such as Carter (1984), Heltberg (1998).

However equation (1) is often criticized for ignoring other factors affecting the efficiency of rural household. These factors include land quality differences, household heterogeneity, land fragmentation and so on. According to the previous studies and data availability, the paper, based on equation (1), introduces some exogenous control variables to control effect of these characteristic variables on the efficiency of rural household. Meanwhile, these characteristic variables can be defined as household endowments (HE), namely, the resources and capabilities of household members and the whole family (including natural and acquired). Household endowments include the human capital and social capital of a rural household owned, such as education, technically training, personal experience, social network and resource availability.

Therefore, the specific equation of estimation used in the paper can be defined as:

$$Efficiency_i^f = C + \beta \ln OP_i + \sum_j \delta_j X_{ij} + \varepsilon_i \tag{2}$$

X_j is the control variables introduced, showing the influence of household endowment (HE), and other variables remain unchanged.

Firstly, the paper discusses the relationship between each household's efficiency indicators and household's land scale, household endowment within the analytical framework of equation (2). Secondly, to further measure the efficiency indicator – TFP which can comprehensively reflex the whole agricultural production process, the paper employs the production function of Cobb-Douglas form to calculate. The function is very concise, easily decomposed and has evident economic implication. Empirical evidences also show that Cobb-Douglas function form is already able to appropriately describe the Chinese agricultural growth and most of studies on Chinese agriculture (for example, Fan, 1991; Zhang and Carter, 1997) use this classical function form.

$$Y_i = A_0 e^{\eta t} K_i^{\alpha_K} L_i^{\alpha_L} M_i^{\alpha_M} \exp(\varepsilon_i) \tag{3}$$

Y_i shows the output level of rural household i, K_i, L_i and M_i represent physical capital, labor and land input of household respectively. α_K, α_L and α_M are their respective output elasticity, t is the time trend term, and η is often called the technological progress rate. When estimating the equation (3), its natural logarithm is often estimated:

$$\ln Y_i = \ln A_0 + \eta t + \alpha_K \ln K_i + \alpha_L \ln L_i + \alpha_M \ln M_i + \varepsilon_i \tag{4}$$

To define $RTS = \alpha_K + \alpha_L + \alpha_M$, and normalize each factor's output elasticity, we obtain: $\alpha_K^* = \alpha_K / RTS$, $\alpha_L^* = \alpha_L / RTS$, $\alpha_M^* = \alpha_M / RTS$.

Then, Total Factor Productivity (TFP) can be defined as:

$$TFP_i = Y_i \big/ (K_i^{\alpha_K^*} L_i^{\alpha_L^*} M_i^{\alpha_M^*}) \tag{5}$$

So we can quantitatively estimate the relationship between rural household's scale, household endowment and TFP through equation (6).

$$TFP_i = C + \beta \ln OP_i + \sum_j \delta_j X_{ij} + \varepsilon_i \tag{6}$$

In addition, the sum of factor output elasticity RTS could be defined as the coefficient of Returns to Scale (RTS). The comparison between RTS and 1 can test the condition of Returns to Scale in the neoclassic economics sense.

Thirdly, the Technical Efficiency (TE) is one of the most commonly used efficiency indicator to measure the efficient state of production units nearly. Generally, from the perspective of input and output, the ratio of the actual output of production units to the maximum potential output is used to measure the TE, in the existing technological conditions. The paper employs Stochastic Frontier Approach (SFA) to estimate rural household's technological efficiency (TE). SFA can take the influence of random errors on technical efficiency while accurately describing the production process. Expressing technical inefficiency index as a set of exogenous variables and a pure random disturbance term and insert to the stochastic frontier production function at the same time, the paper employs B-C (1995) model of Battese and Coelli (1995) and makes a further estimation.

Based on the equation (3), random disturbance term ε_i is expressed as a compound disturbance term $\varepsilon_i = (v_i - u_i)$, and then the average production function can be converted into stochastic frontier production function and the effect of technical inefficiency and pure disturbance term on the agricultural output can be considered at the same time.

$$Y_i = A_0 e^{\eta t} K_i^{\alpha_K} L_i^{\alpha_L} M_i^{\alpha_M} \exp(v_i - u_i) \tag{7}$$

The error term $\varepsilon_i = (v_i - u_i)$ in the equation (7) is a compound error term, consisting of two separate components: v_i is the classical white noise term, $v_i \sim iidN(0, \sigma_v^2)$ mainly includes measurement error and uncontrollable random factors, such as climate change and luck; u_i is nonnegative, representing production technical inefficiency term of rural household i and it is independent of white noise v_i.

In the One-Step Approach, u_i is set as an independent and identically distributed non-negative truncated normal distribution with mean m_i and variance σ_u^2:

$$u_i \sim iidN^+(m, \sigma_u^2) \tag{8}$$

$$m_i = C + \sum_j \delta_j \bullet X_{ij} + w_i \tag{9}$$

m_i corresponds to technical inefficiency function, and e^{-m_i} reflects the technical efficiency level of household i. The larger the m_i, the higher the technical inefficiency degree. X_j represents each exogenous variables determining the technical efficiency level of rural household, and δ_j corresponds the parameter to be estimated, reflecting the impacts of exogenous variables on technical efficiency. w_i is a pure random error term, subjecting to distributed non-negative truncated normal distribution with mean 0 and variance σ_w^2, for instance, $w_i \geq -(C + \delta_j \bullet X_j)$, which can ensure the non-negative nature of u_i.

So we can calculate the level of technical efficiency on this basis:

$$TE_i = E(Y_i | u_i, Z_{ij}) / E(Y_i | u_i = 0, Z_{ij}) = \exp(-u_i) \tag{10}$$

Z_j represents the factor input vector, if $u_i = 0$, then $TE_i = 1$, meaning this household is in the state of total technical efficiency, and its production point is on the production frontier; if $u_i > 0$, then $0 < TE_i < 1$, and this state is called technical inefficiency state, and its production point is below the production frontier. Thus the average technical efficiency is worked out:

$$TE = \frac{1}{n}\sum_{i=1}^{n} TE_i \tag{11}$$

n is the number of rural households. The parametric estimation of stochastic frontier production function determined by the equations (7), (8) and (9) employs maximum likelihood estimate (ML) to estimate jointly. Variance parameters are used in the likelihood function (Battese and Corra, 1977; Coelli, 1995):

$$\gamma = \sigma_u^2 / \sigma_s^2, \sigma_s^2 = \sigma_v^2 + \sigma_u^2 \quad (0 \leq \gamma \leq 1) \tag{12}$$

γ reflects the proportion of technical inefficiency term in all compound variances of the whole compound disturbance term. And whether SFA model is set appropriately can be jugged by examining γ.

2.2 Variable-definition

2.2.1 Input and output variables of rural households

Output variable Y. That the total incomes of crop farming during a year mainly include grain crops and cash crops[8], with the unit of Yuan (RMB). As farmers cultivate different crop varieties, it is unscientific to aggregate directly at the level of output. Therefore, it should uses all kinds of price information of different varieties to aggregate, that is used “magnitude of value” to represent.

Input variable K. The quantity of material costs the farmers put into the crop farming during a year, with the unit of Yuan (RMB). It refers to expenditures of various agricultural means of production consumed during the direct labor process, but does not include period expenses unrelated to the direct labor process. It mainly includes machinery-animal operations, seed-seedling, chemical fertilizer, farmyard manure, agricultural film, farm chemical, water irrigation, fuels and energy, purchase and repair costs of small farm tools and total depreciation on the fixed assets.

Input variable L. Total work days the rural household put into the crop farming during a year, with the unit of “standard working day”. Take a moderate labor normally works 8 hours as a standard working day, including the direct working days of main producers (family members included) and workers hired during the production process.

Input variable M. The paper adopts the total sown areas the farmers have planted during a year, with the unit of Mu[9]. It takes the impacts of replanting indicators into account, which, compared to using farmland areas, can reflect human efficiency in the utilization degree of farmland resources.

Labor force of a household $Farmer$. It is a variable that needs to be used when measuring rural household’s labor productivity and other related indicators, representing by the number of major labor in a household engaging in agricultural activities.

Cultivated areas of a household OP. It is the most important variable for the research purposes in the paper, and it is also the concept corresponding to the household’s scale, indicating by the actual

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[8] Grain crops mainly include wheat, rice, corn and soybean, and cash crops mainly include cotton, oil-bearing crops, sugar crops, bast fiber plants and tobacco crops.

[9] Mu is a Chinese unit, and 1 mu=666.67 m^2.

land areas the farmer has put into use (or has contracted) during a year, with the unit of Mu. Similar to the existing IR literatures, we directly introduce the variable of natural logarithm form, mainly to determine its coefficient signs of estimation and the significance. It, in fact, examines the non-linear monotonic relationship between the household's land scale and household's efficiency.

2.2.2 Household endowment variables

Formal education level of each farm worker $Education$. According to Barro and Lee (1993), the average years of a labor received normal education in schools are adopted to represent the human capital stock level of a household. In the light of China's actual educational system, the average year of education enjoys by each labor in a household can be specifically expressed as followings:

$$Education = (0 \bullet H_0 + 6 \bullet H_1 + 9 \bullet H_2 + 12 \bullet H_3) / Farmer \tag{13}$$

H_j represents the number of labors at different educational levels in each household. j =0，1，2，3 denotes illiterate and semiliterate, primary school, junior school, senior high school and higher education.

Informal education--technical training. Dummy variable of technical training is set in the paper to measure the effect of which the household participate in the agricultural technical training. And if there is someone in the household has received vocational education or technical training, 1 is taken, otherwise, 0 is taken.

Family background--cadre household. Dummy variable that whether the householder is a cadre at the state, township or village level is set in the paper to measure the impact of family background of a household on the household's efficiency. If it is, 1 is taken, otherwise, 0 is taken. The status of cadre is often linked to capability, and generally, only more capable people can be elected to cadres. The capability is related to production decision-making capacity of the household. And it may likely to have colinearity with the variable of $Education$. Therefore, we have discussed the correlation of these two variables before the estimation, and have found that there is only weak correlation between the two. Thus it has little effect on estimated results, especially in the large samples in the paper.

Land fragmentation variable--$Land \;\; faragmentation$. Land fragmentation is the result of three factors which include resource endowment condition that China has vast population and less farmland, institutional restrictions of land equalization under the household contract responsibility system (HRS), and factor market environment with incomplete land market. In the paper, an average of land area cultivated by the household at the end of the year is used to measure the land fragmentation, namely $Land \;\; fragramentation = OP / NO.$, with the unit of mu/block, in which $NO.$ represents blocks of land cultivated by the household at the end of the year.

Non-agricultural management variable. The paper employs the proportion of non-agricultural income in total annual household's income to measure the effect, that is $Nonfarm \; share$ =non-agricultural income in that year /total household's income.

Market-Participation variable. An important feature of the rural household is that it does not fully participate in the market and its dual nature of production and consumption. The proportion of sold amount in the total annual planting operation income of the household is used to measure this influence, that is $Market$ = total amount of sales in that year / Y .

Credit availability variable. Whether the capital credit market in rural areas is developed or not is an important variable that affect the rural household's efficiency. The paper sets credit availability of the rural household as a dummy variable, and if a household has already obtained a loan from the bank or rural credit cooperative, no matter how much, 1 will be taken, otherwise, 0 will be taken.

2.2.3 Data specification

The data in the paper are based on the annual statistical data form, according to the Chinese Ministry of Agriculture, the 15 fixed observation points at village level of Hubei Province during the year of 1999-2003. There are 431 households each year and 2155 samples totaled in 5 years to form the micro panel data. The paper employs Two-Way Fixed Effect Model (TWFE) of panel data for the estimation of household efficiency regression. While it adopts SFA One-Step method for the estimation of household's technical efficiency, and uses the mature software package of Frontier 4.1 and use the Three Step Maximum Likelihood Estimation for equations (7), (8) and (9). So geographic dummy variable D at village level is introduced to try to control the impacts of factors that cannot be measured and reflected explicitly in different geographical positions (at village level), while that for TWFE model is not introduced in the paper. Finally, an additional explanation is necessary here: the paper employs Rural Consumer Price Index (CPI) and Agricultural Means of Production Price Index (PPI) in Hubei Province respectively to convert variables Y and K into the constant price for the base year of 1999 correspondingly when estimating equation (4) and (7) for the household's TFP and TE[10].

3 Empirical Results and Discussions

3.1 Relationship between land productivity and land scale

The relationship between the household's land efficiency ($Efficiency^1$) and land scale is focused in the paper. "Value of per unit area yield" is used to measure the land productivity, namely $Efficiency^1 = Y / OP$, and equation (2) is used to estimate. Please see the column 2 in Table 1 for the empirical result. The empirical evidence shows that the Inverse Relationship does exist between the household efficiency measured by "Value of per unit area yield" and the household's scale measured by land area. And the coefficient is very significant and its strength is great. It fully shows that the yield per unit efficiency for small rural households in the samples is much higher than big-sized rural households. If we take it as a feature of the traditional agriculture, the evidence accounts that China's agriculture still has the feature of traditional agriculture from the view of IR.

From the perspective of land productivity efficiency, the empirical estimation shows that small rural households, compared to big rural households, do enjoy the comparative advantages. If give the priority to solve agricultural problems, in other words, if the policy goal is only targeted at the ensure of basic food security, continuing to maintain the developing strategy of small rural households is an effective way to achieve the policy goal, without necessary considering the problems such as combine farms or enlarge land area. That is to say, compared to big households in other institutions, small rural households in the household contract responsibility system (HRS) enjoy an advantage in efficiency in land productivity, which makes HRS is necessary and rational in the current era.

Table 1 Empirical Relationship Between Each Efficiency Indicators, Household's Land Scale and Household Endowment

	$Efficiency^1$	$Efficiency^2$	$Efficiency^3$	$Efficiency^4$	$Efficiency^5$
C	985.478***	16.164***	698.044***	-0.104	3.499***
	(46.147)	(1.406)	(84.166)	(0.065)	(0.518)
$\ln(OP)$	-235.463***	2.251***	483.128***	0.136***	0.117
	(24.812)	(0.756)	(45.232)	(0.035)	(0.279)
Education variable	6.391	-0.440***	14.837*	0.001	0.071
	(4.807)	(0.147)	(8.769)	(0.007)	(0.054)
Technical training variable	105.195***	2.457**	102.065*	0.235***	2.228***
	(34.822)	(1.061)	(63.477)	(0.049)	(0.391)
Family background variable	-32.874	-0.266	-87.031	-0.0002	0.246
	(41.524)	(1.266)	(75.695)	(0.059)	(0.466)
Land fragmentation variable	-12.061**	-0.631***	-137.392***	-0.042***	-0.124*
	(6.082)	(0.185)	(11.088)	(0.009)	(0.068)
Non-agricultural management variable	-203.272***	-2.198*	-425.594***	-0.163***	-0.892**
	(37.680)	(1.148)	(68.696)	(0.053)	(0.423)
Market-participation variable	-51.480***	-0.782*	-80.694***	-0.063***	-0.586***
	(13.296)	(0.405)	(24.238)	(0.019)	(0.149)
Credit availability variable	-44.794	0.481	27.897	-0.011	0.720
	(47.941)	(1.461)	(87.393)	(0.068)	(0.538)
Log-likelihood	-15097.80	-7575.20	-16384.01	-957.95	-5422.61
Adjusted-R^2	0.437	0.401	0.656	0.465	0.267
F-statistic	4.778***	4.259***	10.279***	5.227***	2.779***

Note: *, **, *** refer to t test values for each variables is significant at the level of 10%, 5% and 1%

[10] Price factor is a problem that must be faced in the use of the panel data to make input-output analysis. Accurately, there are differences between price changes in output and input factors, which should be treated differently, and be processed with corresponding price index. However, due to the constraint of price index data, the official publication of "a basket" price index has been adopted to make the adjustment. The paper, in the general way, employs Rural CPI and Agricultural Means of PPI to process correspondingly.

respectively, within the（）is standard error.

Data source: It is measured according to the fixed observation points in rural areas in Hubei Province of the Chinese Ministry of Agriculture from 1999-2003.

3.2 The relationship between labor productivity and land scale

We construct two labor productivity indicators respectively to test their relation with household's land scale. The first is the labor productivity that based on the household's actual working days of the labor input ($Efficiency^2$), namely, the household's labor productivity $Efficiency^2 = Y / L$. The second is the labor productivity based on the number of household's labor force who engaged in agricultural activities ($Efficiency^3$), namely, household's labor productivity $Efficiency^3 = Y / Farmer$. Please see the column 3 and 4 in Table 1 for the estimated results by using equation (2). Evidences show that whether "the average output value of the actual working day of labor input" or "the average output value of the number of the labor force", highly significant positive relationship (PR) does exist between the household's efficiency measured by the labor productivity and its land scale. In particular, the positive relationship is more obvious in "the average output value of the number of the labor force ($Efficiency^3$)" measured by number of the household's labor force who engaged in agricultural activities.

From the view of household's labor productivity or increasing the incomes of farmers, big rural household, compared with small rural household, enjoys comparative advantages in the term of labor productivity. Combined with IR of land productivity, it is rational to maintain the household contract responsibility system (HRS) at the present era. However, it is necessary to take the lead in exploring new forms of land transfer, encouraging and supporting households to make voluntary subcontract, transfer, exchange and other forms of transfer in some eastern coastal areas and it will certainly become the major trend for China's future agriculture.

The positive relationship (PR) between household's labor productivity and land scale provides empirical evidence for the explanation of inverse relationship (IR) between the land productivity and land scale, namely small rural household, compared with big rural household, put more labor in a unit of land area, so the small rural household is more labor intensive in a unit of land area the big rural household. In absence of the non-agricultural employment opportunities and under the dual separating economy between rural and urban such as production factor market, small rural households tend to use too much self-labor in production to replace for other factors, such as capital, land. And the rural household's self-labor that cannot price according to supply-demand relations in labor market has low opportunity cost, however, the land and capital factor prices are relatively high, particularly, rural household's self-labor can easily be complementary with agricultural variable inputs. It is easy to form intensive cultivation in traditional agriculture, with higher land use intensity. Corresponding to it, there is an intrinsic difficulty for monitoring and measuring labor in agricultural production. With the increase of household's scale and employed labor force, not only the monitoring cost and management cost increase, but should pay wages in accordance with neo-classical law in labor market as well. Overall, big rural households often tend to use more capital such as agricultural machinery to replace labor force, and the land use intensity is low, while small rural households are easier to form "the Involution" agriculture which named by Huang Philip C. C. The co-existence of the inverse relationship (IR, between land productivity and land scale) and the positive relationship (PR, between land productivity and land scale) in the paper shows that the view of high labor input intensity of small rural households for interpretation of IR is tenable. Precisely because China's current natural resources endowment is characterized by abundant labor factor, scarce land and capital factor, from prices of the whole society rather than from the perspective of private sector prices, social efficiency of small rural households is clearly higher than that of big rural households. However, with the factor endowment structure is gradually upgrading and dynamic comparative advantages changes, rural household's land scale will be gradually enlarging, and it will becomes an important result for the changes of Chinese comparative advantages in the future.

3.3 The relationship between profit rate of cost and land scale

In traditional view of economics, peasants are often defined as "backward", "traditional" and even "footling", and cannot respond to price change or market opportunity. But Schultz (1964) overturns the tradition. He believes that the peasants like other economic entities, with its own objective function and special constraint conditions, having achieved the most efficient resource allocation under their own constraint conditions, namely the assumption of “poor but efficient”. This hypothesis adds profit maximization behavior to peasants or farmers who then are good at cost-benefit calculation and may respond to changes in market prices. Therefore, the paper continues to examine whether the small rural households and big rural households have differences in profit maximization and rational behavior. As have proved before, big rural households and small rural households will generate different economic decision behaviors in front of their differences in labor costs. And because small rural households have low opportunity cost in their own labor, factor market of labor force has a forceful interpretive power in explaining the co-existence of IR (land productivity) and PR (labor productivity). Thus, we have constructed two indicators of profit rate of cost to distinguish the differences the small and big rural households in front of the labor costs, and to further provide empirical evidences for the explanation of the factor market of labor force. One indicator refers to profit rate of cost indictor including household’s labor input cost ($Efficiency^4$), $Efficiency^4 = (Y - K - L \bullet P_L)/(K + L \bullet P_L)$, P_L shows the price of labor force, employing labor cost pre day in labor employment (standard labor force) during that year in rural areas of Hubei Province to calculate. Another refers to profit rate of cost indictor without including labor cost ($Efficiency^5$), $Efficiency^5 = (Y - K)/K$.

Please see the column 5 and 6 in Table 1 for the estimated results by using equation (2). The empirical evidences show that it leads to totally different results in relationship of land scale and the profit rate of cost indicator including or not including labor cost. From our calculation of household’s profit rate of cost indicator including labor cost, great majority of rural households indeed have negative profit rate of cost, that is to say, from the perspective of complete cost accounting, most rural households gain losses or even on the brink of bankrupt in the long term. And we can see clearly that the complete accounting for profit rate of cost including household labor cost has significant positive relationship (PR) with land scale from column 5 in Table 1, though with not very big coefficient, yet it is highly significant. By contrast, from the rural household’s profit rate of cost indicator without including labor cost, household’s profit rate of cost is basically positive, namely, it is profitable in the long run. And the indicator is unrelated with scale, which can be clearly see form $\ln(OP)$ in column 6 in Table 1, and there is no significant difference in profit rate of cost between big and small households without accounting for labor cost.

In other words, in considering labor cost, big rural households, compared with small rural households, enjoy comparative advantages to a certain degree on the profit ratio of cost. Without considering labor cost, profit rate of cost is basically unrelated with household’s land scale. According the definition of the price of labor factor P_L in the paper, to assume that small and big rural households face the same labor price of factor market, namely, to set price at average labor cost pre day in labor employment in rural areas of Hubei Province, without considering the specific situation that different non-agricultural employment opportunities cause different labor opportunity costs, big rural households have significantly higher profit rate of cost than small rural households to a certain extent. Whereas in the use of capital factor input showed only by material costs, there is no difference in cost-benefit calculation between big and small rural households. And it proves the earlier judgments once again, in fully considering household’s complete costs of management, that is considering farmers’ self labor costs, small households have less profit rate of cost than that of big households, and with basically negative value (in loss). Therefore, this could mean that small rural households have “self-exploitation tendency” ignoring their own labor cost during management. They overuse their own labor to replace other factors, forming “the Involution” agriculture of labor factors. And there is no difference in the only use of capital factors between big and small rural households.

The empirical evidences in the paper do not prove pseudo hypothesis of “rational” small peasants, but it is further proof of its existence. Because both big and small rural households are making efforts to maximize their objective function, or have the pursuit of profit maximization, for no other reason than that the two face different constraints conditions, it resulted in different economic decision-making (behavior). Especially, they have great decision-making behavior on the differences of factor costs (labor cost in particular). And because of “rational” behavior of small peasants, it enables them to make different adjustments and responds to different economic constraints conditions, resulting in different economic consequences. An additional explanation is necessary that the value of coefficient is not very large from the estimation.

3.4 The relationship between total factor productivity and land scale

Single factor productivity indicator has its important policy implication, but it can often reflect the effect of a certain production factor on output and its changes. For instance, rural household's land productivity and labor productivity obtain different conclusions (PR coexists with IR) when estimating land scale respectively. Just because that variety of production factors is needed in the process of agriculture production, usually, factors can be replaced among each other during the production process, and also factor prices can reflect their scarcity respectively. In particular, the households will make active and rational responds to when each factor's price changes in the factor market. Just has mentioned above, that the small rural households tend to over use their own labor to replace other factors is just the case. An indicator that can fully reflect the comprehensive use of factors during the process of production needs to reflect household's efficiency, and the Total Factor Productivity (TFP) indicator is usually constructed in economics, namely, the ration of total output to weighted factor input. In accordance with the preceding analysis steps, the paper firstly estimates the output elasticity of each factors in household's production function (equation 3 and 4) through TWFE model of panel data, and then calculates the TFP indicator (equation 5), and estimates the equation (2) and (6) to examine the relationship between household's Total Factor Productivity (TFP) and land scale.

From each factors' output elasticity (Column 2 in Table 2) estimated from empirical evidences, the output elasticity of the land factor represented by cultivation areas is the largest, next is the output elasticity of capital factor represented by material cost, the output elasticity of labor input factor is the smallest and has the phenomenon of technological progress in the panel data to a certain degree. It is in the same with the general observation to the characteristics of Chinese agricultural resource endowment, that is, land is the most rare production factor in agricultural production, and capital input also plays an important role in agricultural developing process (Wu, 2005), only the labor force is the most abundant factor and its output elasticity is the smallest, but still no signs of the so called "the Involution", because the output elasticity coefficient is positive. From the coefficient of Returns to scale (RTS), Wald test shows that the hypothesis RTS=1 cannot be rejected, which supply evidence for the point of agricultural constant returns to scale in the general economics sense.

Please see Column 4 in Table 2 for the estimation results of the empirical relationship between the household's total factor productivity's and land scale and household endowment by using equation (2) and equation (6). Although we can initially determine that there may be inverse relationship between household's TFP and land scale to a certain degree, yet the inverse correlation is not significant and its value is small. Thus, the paper holds that the household's TFP is basically unrelated with land scale, that is, there is no significant difference in comprehensively use factors like land, labor and capital between small and big rural households, with no evidences of IR or PR. In view of the meaning of TFP in economics, which indeed, is in the same with the preceding estimations of co-exist with IR (between household land scale and land productivity) and PR (between land scale and labor productivity), for factors can replace each other to a certain extent, there is no significant difference in the TFP between small and big rural households.

Table 2 Household's Total Factor Productivity Estimation and Its Empirical Relationship with Land Scale and Household Endowment

Production function estimation	Coefficient and significance	Each exogenous variables	*TFP*	*Efficiency*[6]
$\ln A_0$	4.173^{***} (0.157)	C	72.903^{***} (3.812)	5061.119^{***} (540.708)
α_K	0.299^{***} (0.021)	$\ln(OP)$	-1.776 (2.049)	-270.851 (290.581)
α_L	$0.106*^{**}$ (0.024)	Education variable	0.614 (0.397)	25.634 (56.332)
α_M	0.552^{***} (0.032)	Technical training variable	18.504^{***} (2.876)	-184.865 (407.794)
η	0.024^{***} (0.006)	Family background variable	-1.073 (3.430)	861.379^{*} (486.283)
$RTS = \alpha_K + \alpha_L + \alpha_M$	0.957	Land fragmentation variable	-0.953^{*} (0.502)	-72.566 (71.232)
Wald Test ($H_0 : RTS = 1$)	2.004 Cannot reject	Non-agricultural management variable	-12.444^{***} (3.112)	357.163 (441.323)
α_K^*	0.312	Market-participation variable	-7.664^{***} (1.098)	152.519 (155.713)

α_L^*	0.111	Credit availability variable	-4.921 (3.960)	2325.498*** (561.437)
α_M^*	0.576			
Log-likelihood	-830.486	Log-likelihood	-9723.653	-20390.630
Adjusted-R^2	0.826	Adjusted-R^2	0.256	0.482
F-statistic	24.513***	F-statistic	2.679***	5.536***

Note: *, **, *** refer to t test values for the variables test through the significance level of 10%, 5% and 1% respectively, within the（）is standard error.

Data source: It is measured according to the fixed observation points in rural areas in Hubei Province of the Chinese Ministry of Agriculture from 1999-2003.

3.5 The relationship between technical efficiency and land scale

Technical Efficiency indicator reflects the popularity and applications of the existing advanced technology, and is one of the most commonly used indicator to measure efficiency. The paper gives up the traditional "Two-Step" estimation, using Battese-Coelli (1995) model of SFA, makes "One-Step" estimations for the relationships between rural household's technical efficiency (TE) and land scale, and other exogenous factors by employing Equation (7), (8) and (9). Compared with the traditional "Two-Step" estimation, only "One-Step" parametric estimation is effective and unbiased. Please see Table 3 for the empirical results.

From the estimation results of production function (Column 2 Table 3), the estimation results are basically the same as the average production function model previous used by estimating TFP. In the output elasticity of each factors, the output elasticity of the land factor is the largest, next is the capital factor, the output elasticity of labor input factor is the smallest and also has the phenomenon of technological progress to a certain degree. And there is no signs in increasing or decreasing returns to scale for the coefficient of RTS (RTS=1.004), with property of constant returns to scale. From the Comparison of these two models, the rural household's production function is robust in the previous discussion. However, from the weight of technical inefficiency term γ (γ=0.966) in the compound variances, the technical inefficiency term contributes larger proportion, so using SFA model is better than the average production function estimation to a certain degree, but from the comparison between two estimations, it will not change the conclusions obtained before.

Table 3 Stochastic Frontier Production Function Estimation for the Empirical Relationship Between the Household's Technical Efficiency, Land Scale and Household Endowment

Frontier Production Function:	Coefficient of estimation	t test value	Technical inefficiency function	Coefficient of estimation	t test value
$\ln A_0$	3.995*** (0.141)	28.264	C	-7.227*** (0.892)	-8.102
α_K	0.263*** (0.015)	17.132	$\ln(OP)$	0.018 (0.133)	0.138
α_L	0.107*** (0.018)	6.032	Education variable	-0.345*** (0.034)	-10.068
α_M	0.634*** (0.022)	29.151	Technical training variable	-2.437*** (0.515)	-4.735
η	0.037*** (0.005)	7.636	Family background variable	0.772*** (0.139)	5.559
σ^2	2.769*** (0.345)	8.026	Land fragmentation variable	0.034* (0.023)	1.493
γ	0.966*** (0.005)	188.906	Non-agricultural management variable	0.169 (0.204)	0.828
TE	0.786		Market-participation variable	0.662*** (0.087)	7.583
Log-likelihood	-1109.321		Credit availability variable	-0.539* (0.416)	-1.295
LR Test	354.540				

Note: *, **, *** refer to t test values for the variables test through the significance of 10%, 5% and 1% respectively; It is generally assumed that LR statistics asymptotically distribute the chi-square or mixed chi-square distribution; Differ from normal estimating equations, the negative sign of coefficient in the technical inefficiency equation shows positive effect of exogenous variables on technical efficiency, and positive sign shows negative effect. Within the ( ) is standard error.Data source: Same as Table 1.

From technical inefficiency function, there may be inverse relationship between rural household's technical efficiency and land scale to a certain extent, but the inverse relationship is highly insignificant and its value is small. Therefore, the paper believes that household's technical efficiency is basically unrelated with the land scale, namely, there is no significant difference in the employment and use of agricultural advanced technology and the achievement of the maximum potential output capacity between big and small rural households. Generally speaking, agricultural machinery technological progress represented by mechanical power changes tends to replace labor factor, and is capital intensive, for the scale bias feature caused by its indivisibility will make certain requests to household's land scale. But just as Ellis (1993) has pointed out, the net welfare effect is more of factor substitution effect rather than productivity growth effect. As a pure technological progress, agricultural biological seed technology represented by breeding technique changes is variable input-intensive and scale-neutral. And itself and complementary inputs can be subdivided indefinitely, with no request for household's land scale, but requires labor input particularly. Its net welfare effect is more of productivity growth effect rather than factor substitution effect. Agro-chemical technological progress such as the use of chemical fertilizer tends to replace land so as to improve land productivity, and similarly, it raises no requirements to household's land scale, and it is scale-neutral too. Taking it as a whole, Hayami and Ruttan (1985) once considered that the modern agricultural technology mostly tends to neutral, and the scale variable cannot turn to be an efficient variable into the decision making of farmers. The empirical evidences shown by Madhu Khanana (2001) also indicate there is no significant relationship between agricultural technical diffusion and land scale, but the adoption and diffusion of the complex agricultural technology (such as agricultural machinery) have significant positive correlation with household's land scale. In a word, the paper finds that big and small rural households measured by land scale are unrelated with scale in agricultural technical efficiency.

4 Conclusions

Using the farm-level micro panel data from Hubei province in 1999-2003, the paper, from the comprehensive perspectives of the land productivity, labor productivity, profit rate of cost, TFP and technical efficiency (TE) etc., discusses the relationship between rural household's efficiency and household's scale measured by its land scale. It not only made up the possible errors resulted from the previous IR studies which often inspected from yield per unit (land productivity) only and provides a new perspective for the IR studies, but it also enriches the case studies on Chinese rural areas in this field. Meanwhile, the paper has made an analysis on exogenous factors that effect rural household's efficiency from the household endowments, and tries to draw some meaningful conclusions.

Basic conclusions can be summarized as follows: From the relationship between the overall rural household's efficiency indicators and land scale, land productivity and land scale are Inverse Relationship. Both household's labor productivity measured by actual working days of labor input and by the numbers of household's labor force has significant Positive Relationship with land scale. The comprehensive profit rate of cost including labor cost shows significant Positive Relationship with land scale, but the profit rate of cost which not includes labor cost is Unrelated with land scale. Both the TFP that reflects the farmers' comprehensive utilization efficiency of agricultural resources and the technical efficiency (TE) that employs agricultural advanced technology to achieve the maximum potential output capacity are Unrelated with land scale. And the efficiency indicator of the rural households' total income considering non-agricultural income is Unrelated with the land scale. In view of the distinction between the two "scale" mentioned above, the discussions of the relationship between the land productivity, profit rate of cost, TFP, technical efficiency and land scale in the paper actually explain the relationship between the total scale of production unit and scale economy. And the discussions of the relationships between labor productivity and households' land scale actually accounts the relationship between per capita land scale and the utilization of agricultural labor. The comprehensive study of each efficiency indicators shows that the small rural households, with scare non-agricultural employment opportunity and under the dual separating production factor market conditions, own low labor opportunity cost and do have "self-exploitation" tendency ignoring their own labor cost. They overuse their own labor to replace other factors, forming the co-existence of IR (between land productivity and land scale) and PR (between labor productivity and land scale), and the labor intensive agriculture. And it leads to different performances for profit rate of cost efficiency indicator including or not including labor cost. However, there are not significant differences between big and small rural households in other efficiency indicators like TFP, TE *etc.*

Therefore, from the perspective of households' land scale, it depends on the policy objects we need to give priority to in the whole policy guidance to determine whether to carry out big or small rural household development strategy. From the agricultural policy for guaranteeing food security and ensuring effective supply of agricultural products, compared with big household, small household enjoys comparative advantages in land productivity. For the agricultural resource endowment that China has vast population and less farmland, the household contract responsibility system (HRS) still remains an effective institutional arrangement and has high social efficiency. Thus we will continue to stabilize and improve the basic institution for rural agricultural managements and continue to effectively stabilize farmland contract relationship and to safeguard peasants' all rights of land contract. But from the view of labor productivity, increasing farmers' income and welfare and comprehensively improving agricultural economic benefit, compared with small household, big household enjoys comparative advantages in labor productivity and the overall profit rate of cost including labor cost, and has higher private efficiency. Therefore, it's necessary to improve farmland contractual management right market and to encourage to take the lead to explore and test new forms of land transfer in some eastern coastal regions while stabilizing agricultural basic management institution (HRS) at the same time. After all, it is an important developing direction for China's rural areas. From the overall agricultural resource allocation efficiency (TFP) and adopting capacity of advanced agricultural technology (TE), the so-called Inverse Relationship (IR) does not exist. There is no significant difference between big and small household in comprehensive utilization efficiency of agricultural resources and in the technical efficiency that employs advanced agricultural technology to achieve the maximum potential output capacity. These two efficient indicators are Unrelated to the land scale. And so does the profit rate of cost without considering labor cost, showing unrelated with land scale.

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