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Impact of land fragmentation on rice producers' technical efficiency in South-East China

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ABSTRACT

Rice farming is important for income generation in large parts of China and Asia. This paper uses detailed household, crop- and plot-level data to investigate the levels and determinants of rice producers' technical efficiency for three villages with different characteristics in a major rice-growing area of South-East China, focusing in particular on the impact of land fragmentation. Empirical results obtained by applying a stochastic frontier model showed statistically significant differences in technology level among villages, with the remotest village having the lowest technology level. Within villages average technical efficiency was generally high, ranging from 0.80 to 0.91 for the three types of rice that are grown in the region. For late-rice producers, no statistically significant variation was found in their technical efficiencies. Land fragmentation was found to be an important determinant of technical efficiency in early-rice and one-season rice production. An increase in average plot size increased rice farmers' technical efficiency. Given average plot size, an increase in the number of plots was found to increase technical efficiency, indicating the presence of variation effects. A larger distance between homesteads and plots contributed to technical inefficiency in early-rice production. The high levels of technical efficiency found in our study support the view that to raise rice productivity in the long run, new technologies need to be introduced.

1. Introduction

Rice is the staple food for 3 billion people worldwide. Of the world's 1.1 billion poor people with an income of less than one dollar per day, almost 700 million reside in the rice-growing countries of Asia, including China. Throughout China, rice is grown on 20% of its cultivated area and constitutes 48.2% of its grain production; besides, over 58% of the Chinese population use rice as main staple food [1]. Rice farming is therefore important for food self-sufficiency and income generation in large parts of China. However, land fragmentation may be a major bottleneck for improving productivity in rice farming [2,3], as found in other Asian countries [4,5]. Due to high population pressure, the limited availability of arable land and the prevailing system of land use rights distribution, land fragmentation in China is very severe. In 1999, farm households in China cultivated on average an area of 0.53 ha, spread over 6.06 plots [6].

In this paper we intend to examine the levels and determinants of rice producers' technical efficiency (TE), focusing in particular on the impact of land fragmentation, with the aim to investigate to what extent rice production can be improved under existing technologies.

Experiences with quantifying the impact of land fragmentation on agricultural production efficiency at micro level in China are scarce. Available studies include Nguyen et al. [7], who used data from a survey conducted among 1200 households in Jilin, Shandong, Jiangxi, Sichuan and Guangdong Provinces in 1993–1994 to examine the impact of land fragmentation on the productivity of three major grain crops. The results indicate that controlling for total holding size, there is a statistically significant and positive relationship between plot size and output of maize, wheat and rice. Wan and Cheng [3] explored the impact of land fragmentation and returns to scale in the Chinese farming sector, using the same rural household survey data set. Their main finding was that an increase in land fragmentation by one plot leads to output losses of 9.8%, 6.5% and less than 2%, in root and tuber crops, wheat and other crops, respectively. Earlier research undertaken by Fleisher and Liu [2] used data from a survey among 1200 households in Jilin, Jiangsu, Henan, Hebei and Jiangxi Provinces in 1987–1988 to examine the effect of land fragmentation, as measured by number of plots, on productivity. Their main finding was that the number of plots had a negative impact on agricultural production. They estimated that a 10% increase in the number of plots resulted in a 5.7%

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reduction in output. These studies used partial measures to examine efficiency and failed to distinguish between the productivity differential caused by land fragmentation and by other factors like farmer's age (experience) and education level. Methods that can deal with these deficiencies are required for obtaining improved estimates of the impact of land fragmentation on TE. In a recent study of the impact of land rental market participation and off-farm employment on TE for 52 households in three villages in north-east Jiangxi, Feng [8] included the number of plots and the distance to the homestead among the control variables. His study showed that the number of plots had a negative impact on TE whereas the distance to the homestead was not statistically significant.

Commonly used approaches in efficiency analysis distinguish parametric and non-parametric methods. Empirical analyses of agricultural producers' efficiency, using both Stochastic Frontier Analysis (parametric method) and Data Envelopment Analysis (non-parametric method) approaches, are in abundance [9–13]. During the last decades, many studies have applied efficiency measurement to the agricultural sector, using frontier methods [14–20]. Relatively recent work includes Chen and Song [21], who used meta-frontier analysis to investigate the efficiency and technology gap in China's agriculture. Studies that investigated efficiency in rice production include Daryanto et al. [22], who analysed the technical efficiencies of rice farmers in West Java, and Coelli et al. [23], who applied non-parametric methods to analyse rice cultivators' efficiency in Bangladesh. Although the latter study used one of the most exhaustive lists of farm-specific variables that any efficiency analysis has used, land fragmentation was not included.

Among the numerous empirical applications, only few have taken land fragmentation into account. A study by Hazarika and Alwang [24] showed that plot size had a significant positive effect on cost efficiency of tobacco cultivators in Malawi. Research from Bangladesh [25] indicated that on average farmers with larger plots operated at higher levels of technical and allocative efficiency. On the other hand, land fragmentation measured by number of plots and distance was found to have no statistically significant effect on the efficiency of Nepal's rice producers [12]. Sherlund et al. [26] tested smallholder technical efficiency, controlling for plot-specific environmental conditions, in Ivory Coast, using 464 traditional rice plots. TE was found to be higher for those who cultivated three or more rice plots.

Recent research by Rahman and Rahman [27], who examined the impact of land fragmentation and resource ownership on rice producers' TE in southern Bangladesh, using data from 298 farms surveyed in early 2000, found that a 1% increase in land fragmentation decreased efficiency by 0.03%. They used the number of plots farmed to measure land fragmentation. Chen et al. [28] examined TE of farms in China's four major regions, using farm household panels covering the late 1990s. They found that land fragmentation, as measured by the Simpson index, was detrimental to efficiency, controlling for the number of plots. TE increased when the number of plots increased from the first quartile to the second and from the second to the third, but decreased when the number of plots increased from the third to the highest quartile. In their paper, different fertilizers were aggregated in terms of their monetary value per household. The field survey conducted for our research indicates, however, that farmers tend to use at least five kinds of fertilizer[1] with different contents of nitrogen, phosphorus and potassium. Because crops may have different responses to different types of fertilizer, a method that simply aggregates the different types of fertilizer into one variable cannot reflect the real crop response to each fertilizer type. Farmers may overuse some kind of fertilizer while underusing another. As Huang [29] pointed out, fertilizer application in China is unbalanced. In this study we shall therefore distinguish fertilizers into nitrogen, phosphorus and potassium in terms of their active contents, i.e., N, P_2O_5 and K_2O, respectively.

In this paper we use detailed household, crop- and plot-level data while controlling other factors, to examine the impact of land fragmentation on rice producers' TE, using a stochastic frontier model. A major difference between our study and previous studies is the way in which land fragmentation, fertilizer and soil quality are measured. For land fragmentation we used a set of indicators that measure its different dimensions, fertilizer use was measured (as mentioned above) by the active macro-nutrient contents, while soil quality was measured by asking farmers' subjective opinions. The remainder of the paper is structured as follows. Section 2 describes the data and sampling frame, while Section 3 discusses the model specification. Results are presented and discussed in Section 4. Section 5 summarizes and elaborates the major conclusions.

2. Sampling and data collection

Data used for this study were collected during a household survey conducted in 2000 and 2001 in three villages in north-east Jiangxi province, covering the agricultural season of the year 2000. The villages Banqiao, Shangzhu and Gangyan were chosen to reflect differences in the degree of market access and agricultural and economic development. They show a high degree of variation in natural resource endowments, rural infrastructure, and land fragmentation, and are considered to be representative of a much larger rice producing, hilly area in Jiangxi and probably also in neighbouring provinces (see Kuiper et al. [30] for details).

Banqiao is the smallest village with around 900 persons distributed over 220 households. Located in a hilly area, 60–70% of its total surface is upland. Market access is good: Banqiao is within 10 km distance from a major city, Yingtan, but the roads from its hamlets to the main road are in poor condition. Irrigation conditions are adequate; paddy fields can be easily irrigated with water from a reservoir, against payment of irrigation fees. In its dryland area, rain-fed agriculture is practised for growing groundnut, fruits, and other cash crops.

Shangzhu is a remote village; it takes about 2 h by bus from the county seat of Guixi county to the major hamlet. Its 16 hamlets are scattered over a mountainous area, with some of them very difficult to reach. The upland area accounts for 97% of its farmland area. In Shangzhu there are 472 households with 2028 persons. The main crops are rice and bamboo. Rice is planted on the terraces of the valley areas, whereas bamboo and fir (a kind of cash tree) are grown in the hilly areas. The terraces are well-constructed with stone, and are several hundreds of years old.

Gangyan is the largest village, with 730 households and 3200 persons. It is located in a plain area at about 30 km distance from the county seat of Yanshan county. Roads are in good condition. The main crops in this village are rice and vegetables. Tractors are used and most of the plots can be irrigated against payment of irrigation fees.

Farmland (irrigated and non-irrigated land) per capita equals 1.89 mu[2] in Banqiao, 1.36 mu in Shangzhu and 1.21 mu in Gangyan. Households were selected randomly. Around 23% of the households were interviewed in each of the selected villages, resulting in 339 surveyed households. Detailed information from 2490 plots was collected. Among the 339 households selected, 264 planted

[1] Farmers used urea, ammonium bicarbonate, compound fertilizer with different nitrogen, phosphorus and potassium combinations, calcium magnesium phosphate and potassium chloride.

[2] 1 mu = 1/15 ha.