CONVERSION FROM CONVENTIONAL TO ORGANIC PRODUCTION: A CASE STUDY OF CHINA'S PADDY RICE FARMERS IN WUCHANG CITY

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Abstract

Based on China's organic paddy rice farmers' data collected from field surveys in Wuchang City, this paper utilises a data envelopment analysis method to estimate the technical efficiency scores of organic paddy rice farmers converting from conventional to organic production. Local organic rice-processing firms provide support to farmers to convert to organic production and, thereby, expand their growing scale. This paper finds that there was no change in crop yields experienced by farmers (N=95) converting to organic. Firstly, there was no statistically significant difference comparing the yields for farmers (N=76) under 'conventional' management and their first year of conversion to organic management. Secondly, there was no statistical difference comparing the yields for farmers (N=19) in their first year of conversion to organic management with their yields in their second year of organic conversion.

Keywords: paddy rice, farmer, data envelopment analysis, technical efficiency.

Introduction

The demand of China's consumers for agricultural products that will relieve the burden on the environment, such as organic agricultural products, has been motivated in part by continuing problems with food safety (Shuo *et al*. 2009; The Lancet Editorial, 2009) and environmental pollution (Wong *et al*. 2002). Meanwhile, the exporting of China's organic agricultural products continues to increase, a result of the increasing growth in recent years of the market for organic products worldwide (Paull, 2007). By 2007, the planting area of organic agricultural products in China had extended from 2.3 million hectares in 2005 to 4.1 million hectares (Sheng *et al*. 2009).

China's paddy rice production plays a key role in ensuring its grain supply, as rice is a staple food feeding more than 60 percent of its population. Paddy rice planting areas lead all other crop planting areas in accounting for 20 percent of the gross crop planting area. Furthermore, China's rice production indicates that the number of organic paddy rice planting areas is increasing. To date, certifications for organic paddy rice plantations have been granted in the Heilongjiang, Jiangxi, Jiangsu and Shandong provinces. Planting areas for organic paddy rice total more than 30,000 hectares of which 60 to 70 percent are located in the provinces of Heilongjiang, Jilin and Liaoning (Jin, 2007). In the Heilongjiang province, one of the main provinces for organic paddy rice cultivation, organic paddy rice growing areas increased from 8,000 hectares in 2004 to 16,000 hectares in 2006. This accounted for an 18 percent share of China's total organic paddy rice growing areas and it also accounted for 1.12 % of the total paddy rice planting area in the Heilongjiang province.

Currently, the land used for paddy rice production in China is divided among the main operators/farmers of relatively small-scale farms. Because farmers engaging in paddy rice production not only face certain market risks but must also pay organic certification costs, an individual farmer is often unable to afford the costs associated with converting to organic production. During the conversion process, the operation modes of "organic firm + growing base + farmer" or "organic firm + growing co-operative + farmer" are available options (Zhang *et al*. 2009). This means that an organic firm selects the organic paddy rice growing base, and farmers convert with the guidance of the organic firm. The organic firm also organises the farmers who belong to the organic paddy rice growing base, allowing them to apply for their organic certifications uniformly.

Wuchang City is located in the Heilongjiang Province of north eastern China and has a long history of growing paddy rice and of possessing rich labour resources. Farmers in the Heilongjiang Province have extensive experience in growing paddy rice which provides a foundation for this type of labour-intensive work. Additionally, several organic rice-processing firms have been built and are promoting the operation mode of firm + growing base + co-operative + farmer. Therefore, Wuchang City is considered a pioneer in the field of organic paddy rice production. By 2008, Wuchang's organic paddy rice planting area had reached

2,000 hectares. Thus, paddy rice farmers in this region serve as representative samples for the analysis of the evolution of technical efficiency scores from conventional to organic production.

In the process of converting, farmers' production technical efficiency impacts not only the enthusiasm level of participating farmers, but also the interest levels of the firms' operations and management teams. There are many studies on farming system conversion (Kerselaers *et al*. 2007). However, few studies focus on technical efficiency analysis during the conversion process at the farmers' level. Therefore, it is increasingly important to perform studies in this field.

In terms of research methods, when researching production technical efficiency, the literature suggests that parametric estimation methods and non-parametric estimation methods are frequently used (Cooper *et al*. 2004; Bravo-Ureta *et al*. 2007). The parametric estimation method, also known as the stochastic frontier production function model, has already been used in organic agriculture production technical efficiency studies (Tzouvelekas *et al*. 2001; Mayen *et al*. 2010). Among the studies on the technical efficiency of paddy rice production in China, the Data Envelopment Analysis (DEA), a non-parametric method, is now widely used (Zhou and Chu, 2003; Wang and Lu, 2006; Zhang *et al.* 2007; Chen and Li, 2008). It mainly utilises average data from the province or country level and focuses on the conventional paddy rice mode. The DEA method had been used in measuring efficiency and productivity of conventional and organic farms in Finland 1994-1997 (Lansink *et al*. 2002). But the DEA has not been used in organic paddy rice production technical efficiency studies. Thus, the DEA method may be an effective method to measure production technical efficiency during the conversion process from conventional to organic production at the farmers' level.

The first section of this paper is the introduction; the second section focuses on clarification of research methods and identification of data sources. The third section contains the analysis and discussion of the findings based on estimated results; and the final section summarises our conclusions.

Methods

DEA method

The data envelopment analysis (DEA) method is a non-parametric estimation method used in the stochastic frontier model. An example of this is the linear programming method which has been used and broadly extended after being introduced by Charnes *et al*. (1978). It has been especially widely used in agricultural production technical efficiency estimation (Coelli 1996a).

This method measures technical efficiency mainly by calculating a constant returns to scale model (CRS) and a variable returns to scale model (VRS) respectively. It then computes for scale efficiency.

The constant returns to scale model (CRS) is as follows:

$$\begin{aligned} \min_{\theta,\lambda} \quad & \theta_c \\ st \quad & -y_i + Y\lambda \geq 0 \\ & \theta_c x_i - X\lambda \geq 0 \\ & \lambda \geq 0 \end{aligned} \quad (1)$$

where θ_c is a constant measure of efficiency of the *i*-th decision-making unit, that is the ith farmer, where if $\theta_c<1$ it denotes that there is a loss of technical efficiency; λ is a constant of N×1 vector; y_i is the paddy rice yield of the *i*-th farmer; x_i is the paddy rice production input of the *i*-th farmer (i = 1,…,M); *X* is an input matrix M×N vector; and *Y* is the paddy rice yield per farmer of 1×N vector.

Some slackness may arise in the solutions with the CRS model. A two-stage estimation method is used to deal with this potential problem (Coelli 1996b).

$$\begin{aligned} \min_{\lambda,OS,IS} \quad & -(M1'OS + K1'IS) \\ st \quad & -y_i + Y\lambda - OS = 0 \\ & \theta_c x_i - X\lambda - IS = 0 \\ & \lambda \geq 0, OS \geq 0, IS \geq 0 \end{aligned} \quad (2)$$

where *OS* is a 1×1 vector of paddy rice yield error per farmer; *IS* is a M×1 vector of input errors, *M*1 and *K*1 are 1×1 and M×1 unity vectors, respectively.

The variable returns to scale model (VRS) is as follows:

$$\begin{aligned} \min_{\theta,\lambda} \quad & \theta_v \\ st \quad & -y_i + Y\lambda \geq 0 \\ & \theta_v x_i - X\lambda \geq 0 \\ & N1'\lambda = 1 \\ & \lambda \geq 0 \end{aligned} \quad (3)$$

where θ_v is a constant measure of efficiency of the i-th farmer; $N1$ is N×1 vector of 1; and the other variables have the same meanings as in equation (1).

Technical efficiency (θ_c) obtained from the CRS model can be regarded as a combination of technical efficiency (θ_v) and scale efficiency (θ_s) derived from the VRS model (where $\theta_c = \theta_v \times \theta_s$). Scale efficiency can be derived from θ_c and θ_v (where $\theta_s = \theta_c / \theta_v$). When scale efficiency equals 1, the production is at optimal scale. When scale efficiency is less than 1, technical efficiency (θ_n) of the non-increase returns to scale model (NIRS), as in equation (4), can be calculated and compared with θ_v, in order to determine in which stage of returns to scale the production lies. When θ_n is equal to θ_v this production is at the stage of decreasing returns to scale. When θ_n is less than θ_v, the production is at the stage of increasing returns to scale.

The concrete form of NIRS is as follows:

$$\begin{aligned} \min_{\theta,\lambda} \quad & \theta_n \\ st \quad & -y_i + Y\lambda \geq 0 \\ & \theta_n x_i - X\lambda \geq 0 \\ & N1'\lambda \leq 1 \\ & \lambda \geq 0 \end{aligned} \quad (4).$$

Data

The data in this paper are the results of field surveys administered to 95 organic paddy rice farmer households living in Taiping Town, Fanshen Town, Hengdaozi Town or Minle Town of Wuchang City. Organic certification is authenticated by the Heilongjiang Lvhuan Organic Food Certification Co., Ltd. The survey covers the years 2006 to 2007. The panel data include 95 cross-section identifiers over two distinct time periods, for a total of 190 gross sample observations. In addition, farmers surveyed all signed purchasing agreements with local organic rice-processing firms.

In order to observe the evolution of paddy rice production technical efficiency during conversion, we classified farmers into two groups based on whether they were using organic fertiliser in 2006 according to paddy rice production data from farmers surveyed in 2006 and 2007. Farmers of one group started the conversion in 2006, meaning that they began using organic fertiliser and reduced their use of inorganic fertiliser and completely abandoned the use of inorganic fertiliser in 2007. This group of farmers is called the 2006TF farmers and includes 19 households. Farmers of the second group did not begin using organic fertiliser until 2007. This group of farmers is called the 2007TF farmers and includes 76 households. Technical efficiency estimated by data from the 2006TF farmers reflects production level changes during the conversion period from a conventional growing mode to an organic growing mode, while technical efficiency estimated by data from the 2007TF farmers reveals production level changes during the turning point from a conventional growing mode to an organic growing mode.

Results

The summary data (Table 1) reveal that while there were variations for such key variables as yield per hectare, planting area and total output, there were no statistically significant differences, across the two years under investigation, either between the two farmer cohorts or within the cohorts. Farmers possibly chose to convert to the organic mode and expand the growing area a result of the support provided by local organic rice-processing firms. In the contracts, firms promised that a payment of CNY 30,000 per hectare (about US$ 4,700 per hectare) would be paid to farmers who had signed agreements, regardless of their paddy rice output.

Table 1. Statistical summary of input and output indicators in paddy rice production

Statistical indicators	Total output	Production inputs							Average household planting area	Yield per unit area
		Organic fertiliser	Farmyard manure	Fertiliser	Labour	Organic biological pesticide and natural extract	Seed	Production facilities and irrigation		
	kilogram	kilogram	cubic metre	kilogram	day	kilogram	kilogram	yuan	hectare	kg /hectare
2007TF farmers										
2006										
mean	16411.8	0.0	25.2	1125.5	115.7	249.4	151.5	1967.8	2.2	7450.5
standard error	12553.3	0.0	46.9	876.5	92.7	221.2	113.1	1688.8	1.7	603.0
minimum	2099.3	0.0	0.0	154.5	27.5	19.2	27.2	171.0	0.3	6000.0
maximum	64020.0	0.0	335.8	3780.0	570.0	1150.1	540.0	9840.0	8.0	9000.0
samples	76									
2007										
mean	17546.7	1430.2	28.1	0.0	138.8	268.6	188.7	2215.1	2.4	7493.0
standard error	13960.6	1173.5	51.5	0.0	144.8	295.2	160.8	2288.1	2.0	495.5
minimum	2400.8	180.0	0.0	0.0	30.0	17.6	29.3	306.0	0.3	6150.0
maximum	62977.5	5400.0	335.8	0.0	924.2	1667.3	840.0	13320.0	9.0	8640.0
samples	76									
2006TF farmers										
2006										
mean	15719.8	1121.8	20.2	293.3	146.7	400.3	150.7	2197.3	2.1	7775.1
standard error	16017.6	1421.7	31.0	562.9	169.7	708.0	182.7	2280.8	2.3	1131.4
minimum	2774.2	174.2	0.0	0.0	12.0	29.4	24.0	435.0	0.3	6502.5
maximum	69975.0	6000.0	126.0	2475.0	769.5	3075.0	750.0	10005.0	10.0	12000.0
samples	19									
2007										
mean	17308.1	1386.3	31.2	0.0	227.9	427.0	174.7	2489.4	2.3	7601.1
standard error	21686.0	1848.9	39.0	0.0	419.9	993.7	239.7	3113.2	3.1	993.8
minimum	2425.8	208.0	0.0	0.0	12.0	10.4	24.0	435.0	0.3	6600.0
maximum	97965.0	8400.0	132.0	0.0	1917.3	4305.0	1050.0	14007.0	14.0	11475.0
samples	19									

Note: 2007TF farmers denote farmers who began to use organic fertiliser and abandon fertiliser input in 2007 instead of in 2006. 2006TF farmers denote farmers who began to use organic fertiliser in 2006, and abandoned fertiliser input in 2007.

Secondly, during 2006 and 2007, the minimum average household total output of the 2007TF farmers ranged between 2099.3 kilograms and 2400.8 kilograms while the maximum value was between 64,020 kilograms and 62,977 kilograms. The extreme difference of average household total output for the 2007TF farmers was far greater than that of the 2006TF farmers. The minimum for the 2006TF farmers ranged between 2425.8 kilograms and 2774.2 kilograms, and the maximum value ranged between 69,975 kilograms and 97,965 kilograms. The variations are primarily due to the differences in size of the average household planting area. While the minimum average household planting area was 0.3 hectares, the maximum average ranged between 9 hectares and 14 hectares, and the maximum planting area of the 2006 TF farmers exceeded that of the 2007TF farmers. Because of the promises contained within the contracts, the farmers were anxious to expand the scale of their organic paddy rice growing.

Third, the data from Table 1 suggests an increase in average household labour when compared with that in 2006. There was also a slight increase in plant disease and insect prevention, seed, production facilities and irrigation improvements when compared with 2006. An increase in average household production was correlated with the corporate culture of local organic rice-processing firms. In addition to signing purchasing agreements with farmers, firms also provided funds and subsidies for education tuition for the farmers' children and housing reimbursements for the farmers which resulted in an increase in labour and, consequently, in paddy rice production. The data suggest that greater input of labour, organic biological pesticide and natural extract, seed, production facilities and irrigation and household planting area, lead to greater output (Figure 1 and Figure 2).

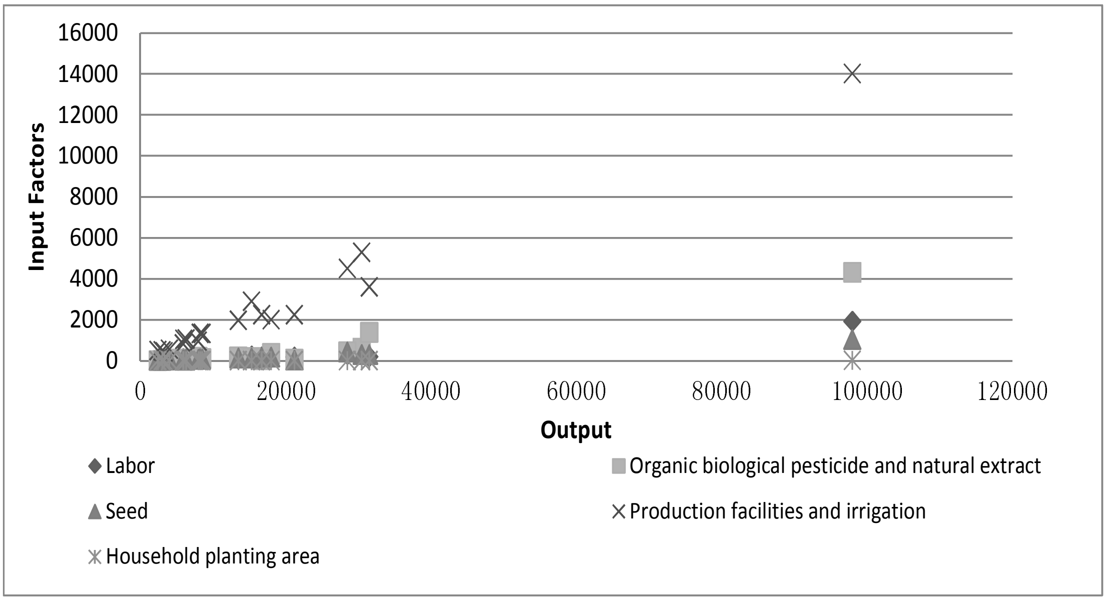

Figure 4. The fluctuation of output and input factors of 2006TF farmers in 2007. The units of output and input factors are the same as that in Table 1.

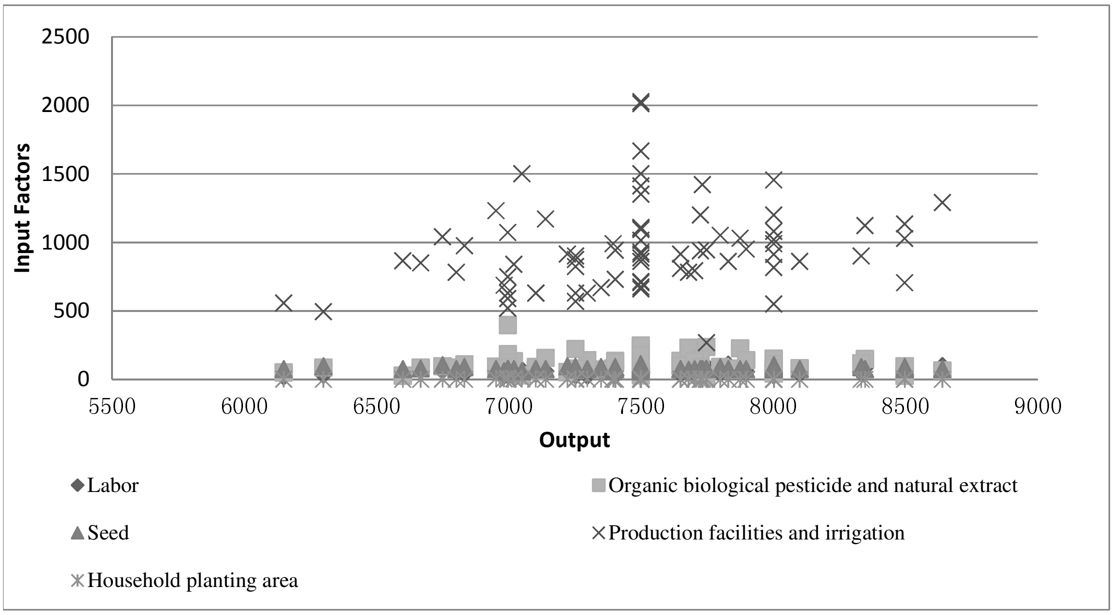

Figure 5. The fluctuation of output and input factors of 2007TF farmers in 2007. The units of output and input factors are the same as that in Table 1.

The results of average technical efficiency scores and scale efficiency scores of paddy rice farmers estimated by the above data and models can be seen in Table 2. According to the results, average technical efficiency scores and scale efficiency scores of the 2006TF farmers showed a downward trend. The average technical efficiency scores of the CRS model declined from 0.982 to 0.892 while the scores of the VRS model dropped from 0.999 to 0.953. Meanwhile, scale efficiency scores fell from 0.983 to 0.936. This reveals that for those farmers who began to convert to organic production in 2006, the average technical efficiency scores of the CRS model decreased over time, and the scale efficiency also decreased.

Table 2. Results of the average technical efficiency and scale efficiency scores

	Technical efficiency scores of CRS	Technical efficiency scores of VRS	Scale efficiency scores	Farmers' percentage in different phases of returns to scale		
year	θc	θv	θs	decreasing	increasing	optimum
2006TF farmers						
2006	0.982	0.999	0.983	0.211	0.000	0.789
2007	0.892	0.953	0.936	0.421	0.368	0.211
2007TF farmers						
2006	0.886	0.922	0.961	0.289	0.329	0.382
2007	0.941	0.966	0.974	0.342	0.382	0.276

Note: Authors' estimated results.

Figure 3 indicates that not only no technical efficiency 2006TF farmers whose scores are less than 1 increase but also 2006TF farmers whose scale of efficiency scores less than 1 increase sharply. The results of 2007TF farmers show similar fluctuations except the technical efficiency scores of VRS which are not changed (Figure 4).

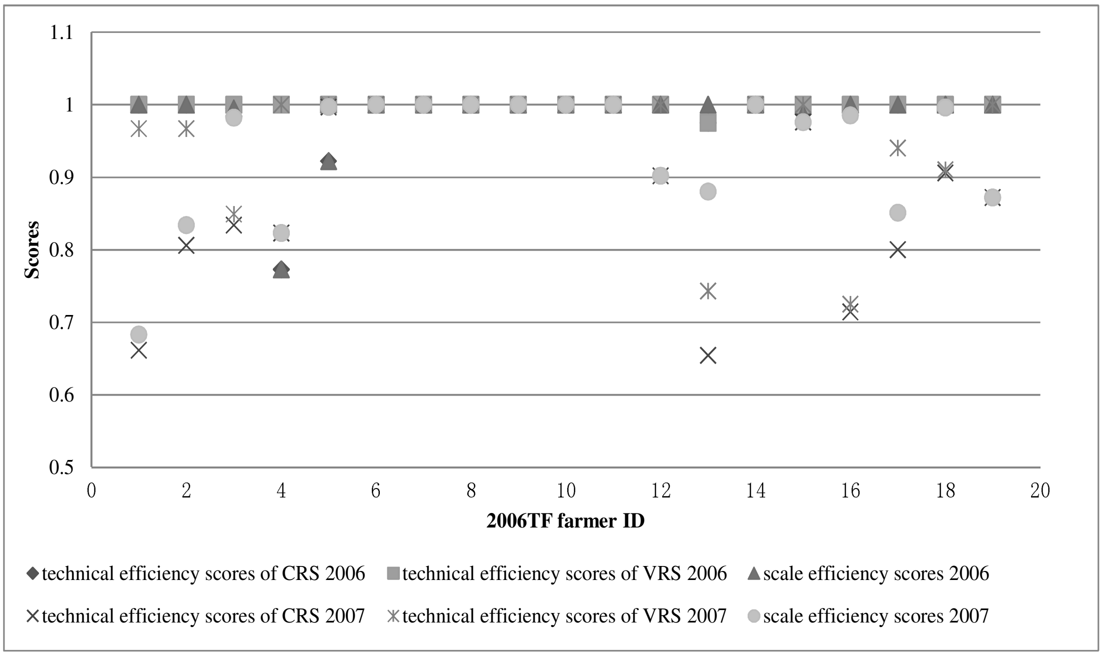

Figure 6. Figure 3. The average technical efficiency and scale efficiency scores of 2006TF famers

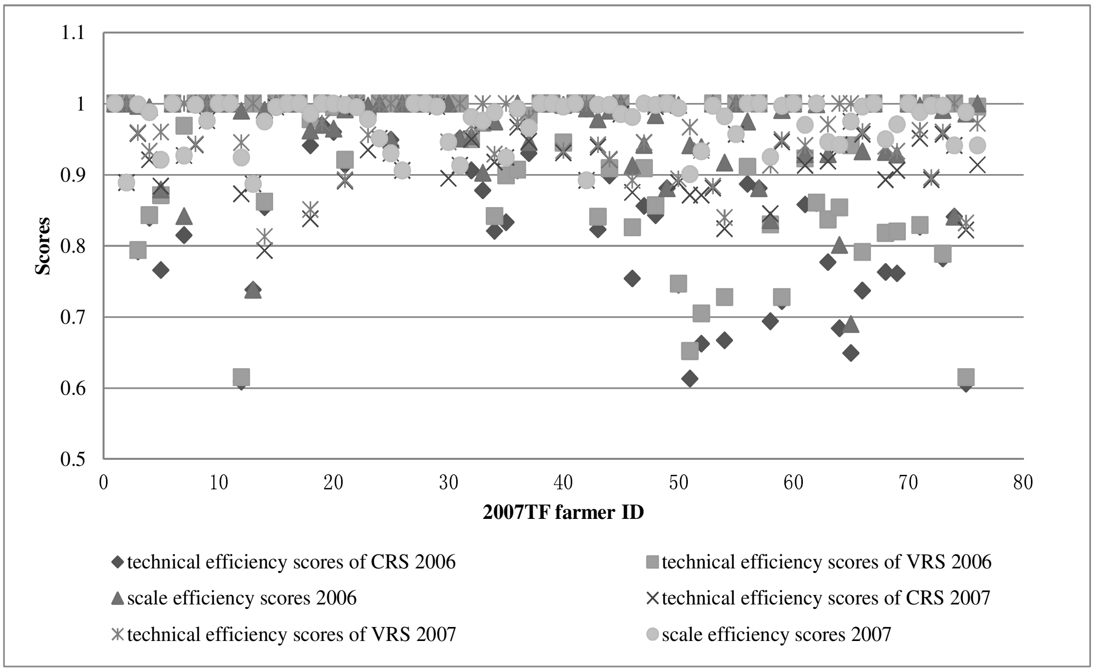

Figure 7. The average technical efficiency and scale efficiency scores of 2007TF famers

On the other hand, average technical efficiency scores and scale efficiency scores for the 2007TF farmers revealed an upward trend. Average technical efficiency scores of the CRS model increased from 0.886 to 0.941 and that of the VRS model rose from 0.922 to 0.966. Similarly, scale efficiency scores rose from 0.961 to 0.974. This indicates that the average technical efficiency of the CRS model of the 2007TF farmers increased, and that the scale efficiency is higher than that for the 2006TF farmers. The technical efficiency of paddy rice production can therefore increase over the short term during the conversion process. However, the influence may lessen over time as the ecological and marketing system for organic paddy rice evolves (Acs *et al*. 2007).

From real input and aimed input of average household paddy rice production (Table 3), as well as aimed input of per hectare paddy rice production (Table 4), the average aimed labour input, organic fertiliser input, organic biological pesticide and natural extract input, production facilities and irrigation input of the 2006TF farmers were higher than those of the 2007TF farmers. Only the average seed input of the 2006TF farmers in 2007 was lower than that of the 2007TF farmers. In the conversion process, real and aimed farmyard manure input and labour input of both the 2006TF and 2007TF farmers increased, whereas the organic biological pesticide and natural extract input decreased. From input percentage for saving in the average household paddy rice production (Table 3) and input percentage for saving in per hectare paddy rice production (Table 4), input percentages for saving of the 2006TF farmers were all lower than those of the 2007TF farmers, except in seed input. Therefore, the longer the conversion period, the greater the dependence on labour input in the organic system. However, as the organic systems develops over time and farmer experience increases, it is likely that labour requirements will decrease (Kristiansen *et al.* 2003), though labour can be expected to remain higher than under conventional systems (Morison *et al.* 2005).

Table 3. Aimed input and input percentage of enabling saving in average household paddy rice production inputs

		Average household production inputs						
		Organic fertiliser	Farmyard manure	Fertiliser	Labour	Organic biological pesticide and natural extract	Seed	Production facilities and irrigation
		kilogram	cubic metre	kilogram	day	kilogram	kilogram	yuan
2006TF farmers	aimed input							
	2006	1117	18	293	144	400	148	2190
	2007	1313	24		214	418	159	2319
	input percentage of enabling saving（%）							
	2006	-0.45	-10.83	-0.04	-1.94	-0.02	-1.66	-0.32
	2007	-5.29	-24.01		-6.20	-2.11	-9.23	-6.83
2007TF farmers	aimed input							
	2006		13	1020	95	195	138	1735
	2007	1391	16		114	217	178	1925
	input percentage of enabling saving（%）							
	2006		-48.57	-9.39	-18.06	-21.80	-8.79	-11.83
	2007	-2.73	-42.52		-17.77	-19.24	-5.65	-13.10

Note: Input percentage of enabling saving = (aimed input - real input)/real input×100%.

Table 4. Paddy rice production inputs per hectare and input percentage of enabling saving

			Production inputs per unit area						
			Organic fertiliser	Farmyard manure	Fertiliser	Labour	Organic biological pesticide & natural extract	Seed	Production facilities and irrigation
			kilogram	cubic meter	kilogram	day	kilogram	kilogram	yuan
2006TF farmers	input								
	2006		503	11	109	74	141	68	1100
	2007		600	15		90	107	73	1122
	2006	*	498	9	109	72	141	66	1094
	2007	*	557	11		78	98	61	1027
	input percentage of enabling saving（%）								
	2006		-0.01	-0.18	0.00	-0.03	0.00	-0.03	-0.01
	2007		-0.07	-0.26		-0.14	-0.08	-0.16	-0.08
2007TF farmers	input								
	2006			12	515	58	119	71	931
	2007		600	13		63	109	79	949
	2006	*		8	455	48	88	64	820
	2007	*	579	9		54	79	74	849
	input percentage of enabling saving（%）								
	2006			-0.36	-0.12	-0.17	-0.26	-0.10	-0.12
	2007		-0.04	-0.28		-0.14	-0.27	-0.06	-0.11

Note: * = aimed input.

Conclusions

The findings from results are summarised below.

First, there was no significant change in consecutive year crop yields experienced by paddy rice farmers (N=95) converting to organic. In particular, there was no statistically significant difference comparing the yields for farmers (N=76) under conventional management and their first year of conversion to organic management. And in addition, there was no statistical difference comparing the yields for farmers (N=19) in their first year of conversion to organic management with their yields in their second year of organic conversion. It is thought that farmers choose to convert to organics and thereby expand the total organic growing area as a result of the support provided by local organic rice-processing firms, especially when that support includes products purchasing, income guarantee and standard of living assurance.

Second, average technical efficiency scores and scale efficiency scores of the 2006TF farmers showed a downward trend while those of the 2007TF farmers increased, thus indicating that technical efficiency of organic paddy rice production might increase in the short run, yet decrease over time. The evolution of the organic ecological and marketing system may require more time to become stable and effective.

Third, labour input, organic fertiliser input, organic biological pesticide and natural extract input, production facilities and irrigation input levels of the 2006TF farmers who had a long conversion period were relatively higher when compared with those of the 2007TF farmers. The dependence on labour was also found to be greater while the labour input percentage for saving in aimed input declined. Therefore, in the conversion process from conventional mode to organic mode, the longer the conversion period, the greater the dependence of the organic system on labour. While, the costs associated with this are not easily reduced, system evolution and farmer experience are likely to reduce labour requirements.

In addition, there are some limits in this paper due to the limited number of participants in the survey, the relatively short survey periods and the absence of details on rainfall, temperature and other climate factors. We recognise that it requires several years to achieve the organic paddy rice producing goal for famers as they transition from conventional to organic production.

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