Effect of Formula Fertilization Technology Subsidy Policy on Rice Production in China: A Case of Xinyang City

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配合施肥技術開発補助政策が中国の稲作生産の効率性に与える効果

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中国では化学肥料や農薬の過度な使用が環境へ及ぼす効果が問題視され、肥料投入を適切に管理する配合施肥技術が注目されている。しかし、高額な費用がその普及の妨げとなっていることから、中国政府は普及を目的とした補助事業を2005年に開始した。そこで本論文ではDEA

を援用し、補助事業が中国の稲作生産の効率性に与える影響の定量的な評価を行った。分析の結果、全ての分析対象地において生産効率率が格段に向上しており、また生産要素の使用が効率化されていることから補助事業の有効性が確認された。

1. Introduction

Excessive use of chemical fertilizers and pesticides causes environment deterioration in China. A series of technical subsidy policies have been implemented to extend new agricultural and environmental technology since 2005. Formula fertilization technology is a well known example. It consists of field investigation, soil sample collection, field experiment, formula design, fertilizer making, and technical support. This technology aims to protect agricultural environment, reduce costs and enhance production efficiency, but has large costs to be implemented. To diffuse this technology, the formula fertilization technology subsidy policy was introduced in 2005. Since then, its effects on environment and agricultural productivity have received much attention from academics and policy makers. For example, Zhang (2009) employed positive mathematical programming (PMP) method to assess the effect of formula fertilization technology in Jiangsu province and found that the formula

fertilization technology helped increase farmers' income. Qu and Guo (2010), Mu and Duan (2009), Wang (2007) and Ying and Yu (2006) compared the fertilizer usage and crop production before and after the technology adoption using field experiments. They found the fertilizer usage has decreased while the production has increased. However, few of them have studied how technical efficiency in crop production has changed due to the subsidy. To fill this gap in the literature, we take Xinyang city as a case and employ Data Envelopment Analysis (DEA) to assess the effect of formula fertilization subsidy policy on technical efficiency in crop production¹⁾.

2. Methodology and Data

DEA is a mathematical programming approach to estimate the relative efficiency of each decision making unit (DMU). It has been widely used in agricultural economics (e.g. Francisco et al, (2010)). The efficiency of a particular DMU is obtained by maximizing a ratio of weighted

outputs to weighted inputs:

$$\max_{u,v} E = u^T y_0 / v^T x_0,$$

subject to $u^T y_i / v^T x_i \leq 1, i=1, 2, \dots, n, u \geq 0, v \geq 0$, where $u=(u_1, u_2, \dots, u_s)^T, v=(v_1, v_2, \dots, v_m)^T$ are weighting parameters for s outputs and m inputs, respectively; y and x represent outputs and inputs; n indicates the number of the DMUs; The subscript zero indicates the particular DMU to be evaluated.

The above model yields two production indices: (i) technical efficiency and (ii) input excess²⁾. Figure 1 illustrates how technical efficiency and input excess are measured by DEA. Suppose two inputs x_1 and x_2 are used to produce a single output y . SS_1 is a unit isoquant. DMU at point P is not efficient in its production because it is located at the above of the isoquant. Its (i) efficiency value E is defined by OP_1/OP , where P_1 is its efficient production level. Hence, E -value takes between zero and one. When E equals to one, DMU's production is efficient and is located on a frontier of the isoquant. On the contrary, resources are not efficiently used if E is smaller than one: the smaller E is, the less efficient the production is. Next, (ii) input excess measures how much inputs can be reduced without changing the output quantities. Namely, MM_1 and NN_1 measure input excesses, i.e. how much x_1 and x_2 can be reduced if production takes place at P_1 on the isoquant. In other words, input excess is observed only if a DMU is not on a production frontier. Larger input excess reflects worse production technology and a decline in input excess implies an improvement in the technology.

Note that targets of this subsidy are counties, not farmers. The funds are subsidized to the department of agricultural extension in each county, and the department uses the subsidy to provide technical services for farmers for free. With technical services such as soil sample collection and formula design, farmers can realize the soil condition of their fields and appropriately control the amount of fertilizers. In 2005, 200 counties were subsidized, and its number has increased annually. Until 2009, 2498 counties were covered by the subsidy policy and four billion yuan had been spent for this purpose.

Xinyang city is a major rice production area in Henan province, which produces more than 80% of rice of Henan province, and in 2010 its rice production reached to 4129 thousand tons. The formula fertilization technology subsidy has been introduced in this area since 2006. Table 1 summarizes the total amount of the subsidy and a starting

Fig. 1. Technical efficiency and input excess

Source: Farrell (1957).

Table 1. Total subsidy funds in each county

County	Subsidy (million yuan)	Starting Year
Gushi	2.5	2006
Xixian	2.5	2006
Shangcheng	2.0	2007
Pingqiao	1.5	2008

Source: Authors' investigation. Note: Values in subsidy are cumulative to 2009 from the starting years.

year for each studied area. Each county in general receives one million yuan in the first year and 0.5 million yuan for the following years.

Formula fertilization technology reduces wastes in crop production by efficiently using fertilizers. Data on three inputs related to this technology, i.e. seed (kg/mu), fertilizer (kg/mu), and pesticide (yuan/mu) and two outputs, yields (kg/mu) and net returns (yuan/mu), are collected from *Cost and Return of Agricultural Commodities Yearbook in Henan Province* for 2003 to 2008 (one mu is equivalent to 0.067 ha). Data for each region is averaged for two periods: before and after the subsidy implementation. This yields eight DMUs, i.e. two DMUs for each county.

3. Estimation Results

(1) Analysis on Technical Efficiency

Table 2 shows changes in E -value in four counties. They are respectively 0.709 and 0.885 in Pingqiao and Shangcheng counties before the subsidy implementation. After the subsidy is implemented, E -values in both counties reach to one and production in these counties takes

Table 2. Changes in technical efficiency before and after the subsidy implementation

County	<i>E</i> -value		Change	Percent Change
	Before	After		
Pingqiao	0.709	1.000	0.291	41.0
Shangcheng	0.885	1.000	0.115	13.0
Gushi	0.902	0.957	0.055	6.1
Xixian	0.513	0.830	0.317	61.8

Source: Authors' calculations.

Table 3. Changes in input excesses before and after the subsidy implementation

County	Before	After	Change	Percent Change
Seed (kg/mu)				
Pingqiao	0.42	0.00	-0.42	-100.0
Shangcheng	0.13	0.00	-0.13	-100.0
Gushi	0.11	0.04	-0.07	-63.6
Xixian	0.85	0.18	-0.67	-78.8
Fertilizer (kg/mu)				
Pingqiao	3.95	0.00	-3.95	-100.0
Shangcheng	1.63	0.00	-1.63	-100.0
Gushi	1.02	0.62	-0.40	-39.2
Xixian	9.07	3.77	-5.30	-58.4
Pesticide (yuan/mu)				
Pingqiao	1.77	0.00	-1.77	-100.0
Shangcheng	5.19	0.00	-5.19	-100.0
Gushi	3.15	2.69	-0.46	-14.6
Xixian	10.31	28.31	18.00	174.6

Source: Authors' calculations.

place on a production frontier. *E*-value for Gushi is 0.902 before the subsidy, and reaches to 0.957 after the subsidy. Rice is least efficiently produced in Xixian. However, the region shows the largest increase in *E*-value after the subsidy. It rises up to 0.830, an increase by 61.8 percent. As a result, *E*-values have increased after the subsidy implementation in all four counties.

(2) Analysis on Input Excesses

The inputs excess values for each county are listed in Table 3. For example, the average farmers in Pingqiao county can reduce 0.42 kg of seeds, 3.95 kg of fertilizer, and 1.77 yuan of pesticide without changing the outputs quantities before the subsidy is implemented. All input excesses become zero after the subsidy because its

production takes place on the frontier after the subsidy implementation (table 2). In Shangcheng county, excess in fertilizer also becomes zero after the subsidy implementation. In Gushi and Xixian counties, excesses in fertilizer drop by 0.4 kg/mu and 5.3 kg/mu, corresponding to a 39.2% and a 58.4% decrease, respectively. This result shows the formula fertilization technology subsidy is effective in reducing fertilizer usage in four counties.

We also find excesses in seeds and pesticide have decreased in most counties. In Gushi county, excesses in seeds and pesticide drop by 63.6% and 14.6%, respectively, after the subsidy implementation. In Xixian county, excess in seeds decreases by 78.8% while excess in pesticide increases by 174.6%. This last finding may reflect pest disasters happened in this area during the period.

4. Conclusions

Employing Data Envelope Analysis, we assess the effect of the formula fertilization technology subsidy policy on technical efficiency in rice production in China. Results show technical efficiency significantly increases in every county after the subsidy implementation, implying the effectiveness of the technical subsidy. Secondly, fertilizer excesses become small after the subsidy implementation, indicating this new technology significantly improves farmers' resource utilization. As a conclusion, Chinese government should enlarge the geographical coverage of the subsidy to diffuse this technology nationwide.

Notes

- 1) The study was funded by the Mode Construction of Modern Farming System and Supporting Technology Research and Demonstration, China (201103001).
- 2) See Charnes et al (1978), Wei et al (1989), and Wei (2001) for the detailed estimation procedures and formulas of these indices. We focus on technical efficiency in this paper because data on input prices are not available at county level and our interest lies in how much inputs can be saved, that is how much the overuse of fertilizer is reduced, by the policy.

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（受理日：2012 年 3 月 1 日）