Cost and Environmental Efficiency of Rice Farms in South Korea

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Abstract: This paper examines (1) the cost and environmental efficiency measures, and (2) the cost to be more environmentally friendly of rice farms in Gangwon province of South Korea. The findings indicate that on average rice farms are far away from economic and environment efficiency, and it is not costless for the farms to be environmentally efficient. It is thus recommended that agri-environmental policies should be redesigned to improve cost and environmental performance of rice farms.

Keywords: *material balance principle, efficiency, rice, South Korea*

1. Introduction

Rice is the most important grain in South Korea. As of 2009, the total cultivated rice area in South Korea was 924,000 ha, accounting for around 53.2% of the total farm land area. Land productivity of rice production increased by 11.9% from 1990 to 2009 (KREI 2010). However, this growth in productivity was achieved at the cost to the natural environment. Environmental challenges for Korea are dominated by the negative impacts of rice cultivation on water and land resources (OECD 2008b). Water pollution caused by nitrates (N) and phosphates (P) has been identified as one of the most serious environmental issues (OECD 2006). The increasing concentrations of these two nutrients in some rivers, lakes, and reservoirs has caused eutrophication of terrestrial and coastal water sources (Kim, et al., 2004). Soyang Lake in Kangwon province, the deepest reservoir in South Korea, is a typical example of such a phenomenon (Kim, et al., 1989).

A primary solution to decrease nutrient surplus is to achieve higher efficiency of nutrient use. We thus aim to examine if cost efficiency of rice farms in this country deviates from nutrient use efficiency. We are also interested in knowing how much it costs to move farms from cost efficient operation to nutrient efficient operation. We approach these two research questions by using a framework proposed by Coelli et al., (2007). We expect this analysis will shed some lights for future policy interventions so that the environmental performance of rice production can be improved.

2. Methods and Data

2.1 Methods

During the past decades, increasing attention has been paid to pollution caused to the natural environment by economic activities. Researchers have recognized the need to adjust traditional methods to integrate environmental concerns into the standard technical and economic efficiency measures. The traditional approach that the majority of empirical studies have taken is that the environmental effect is modelled as either a bad output or an environmentally detrimental input in production functions (Pittman, 1983, Färe, et al., 1996, Tyteca, 1997). All of these methods, however, do not satisfy the material balance principle (MBP) (Hoang and Coelli, 2009).

Given inappropriate interventions in the markets of inputs and outputs, cost efficiency does not warrant environmental efficiency. This happens because farmers are driven by their cost-minimizing considerations while the prices of inputs and outputs do not properly account for the environmental effects of production. Figure 1 is useful to illustrate this phenomenon for simple cases of two inputs (x1 and x2) and one output (q). There are iso-cost line, iso-nutrient line and isoquant curve. Point C is at the tangency of the iso-cost line with the isoquant while the iso-nutrient line is tangent to the isoquant at point N. Point C generates the smallest cost of production whilst point N refers to the smallest consumption of nutrients. Given that the iso-nutrient line is not identical to the iso-cost line, any observed data point like point A exhibits three sources of inefficiency: (i) ITE = OB/OA, (ii) CAE = OC'/OB, and (iii) NAE = ON'/OB. An improvement in ICE could be associated with either an increase in ITE or an increase in CAE or both. Similarly, an improvement in INE could be caused by increases in ITE or/and NAE. Improvements in ITE, therefore, increase both cost and environmental efficiency. However, increases in CAE could result in a rise or fall in INE, depending upon whether this movement is towards or away from the environmentally efficient operation (e.g. point N). Similarly, increases in NAE could result in higher or lower cost, depending upon the direction of movements towards or away from the cost efficient position (e.g. point C).

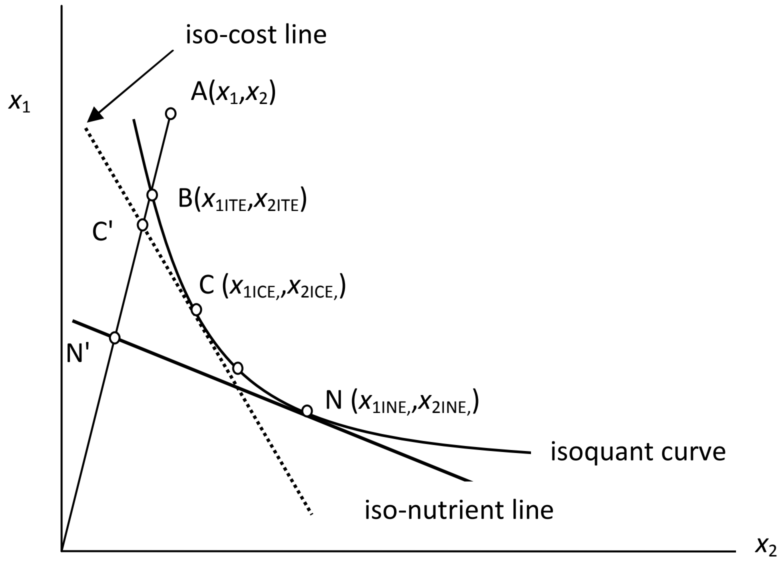

Figure 1. The minimisation of cost and nutrient in inputs

Differences between environmental efficiency and cost efficiency pose several important implications for empirical studies. First, it is possible to calculate how much it costs to move from the cost efficient point (point C) to the environmentally efficient point (point N). This cost could be interpreted as the shadow cost of reductions in the consumption of nutrients. Second, one can measure how much more nutrient consumption would be involved with a movement from the nutrient minimizing point to the cost minimizing point.

2.2 Data

This study used a panel dataset of 96 rice farms from 2003 to 2007. The data were taken from the Agricultural and Livestock Production Cost Survey of the Microdata Service System of the Korean National Statistical Office. Outputs include net rice grain and straw. Inputs include seed, single chemical fertilizers (e.g. urea), complex chemical fertilizers, organic fertilizers, different types of pesticides and insecticides, owned and rented land area, hired and family labor, energy consumption and farming equipments.

As the eutrophication of fresh water is a serious environmental in Kangwon province, two nutrients causing eutrophication, nitrogen (N) and phosphorous (P), were considered. The N and P contents of fertilizers were readily available in the dataset. All N and P inflows and outflows related to atmospheric deposition, biological fixation, precipitation, runoff, detrinification and volatilization processes were estimated using the results reported in other studies (Bashkin, et al., 2002, Yoon, et al., 2006). The presence of two nutrients (N and P) also requires the use of aggregate nutrient contents of land and fertilizers. A constant weight (1 for N and 10 for P), therefore, was recommended to use as in other empirical studies (Coelli, et al., 2007). This weight set is not ideal but reasonable because P has more eutrofying power than N in the context of fresh water (Gold and Sims, 2005). The nutrient content was then identified as the summation of the product of N and P with the respective weights. This aggregate nutrient content was termed as “eutrophying power” (EP = amount of N + 10 x amount of P).

3. Results and Discussion

3.1 Efficiency Measures

The DEA results are summarized in Table 1. The average ICE score was estimated to be 0.498, which suggests that on average farms could reduce total costs by 50.2% without any reductions in the output level. This cost inefficiency is primary due to both technical inefficiency and cost allocative inefficiency. The mean technical efficiency (ITE) score of 0.755 suggests that the average farm should be able to produce their current level of output with 24.5% fewer inputs. The mean CAE score of 0.650 implies that these farms could be able to reduce further production costs by changing the combinations of inputs. The correlation coefficient of ICE scores with CAE is stronger than the correlation of ICE with ITE (e.g. 0.83 and 0.73 respectively), implying that improvements in CAE would have stronger influence on ICE.

Table 1. Cost and environmental efficiency measures

Efficiency measures	Mean	St.dev.	Min	Max
Input-orientated technical efficiency (ITE)	0.755	0.164	0.283	1
Input-orientated cost allocative efficiency (CAE)	0.650	0.171	0.216	1
Input-orientated cost efficiency (ICE)	0.498	0.191	0.123	1
Input-orientated nutrient allocative efficiency (NAE)	0.324	0.210	0.037	1
Input-orientated environmental efficiency (INE)	0.247	0.182	0.032	1

The mean INE score of only 0.247 suggests that on average these farms should be able to produce their current output with an input bundle that contains 75.3% less eutrofying power of nutrients (in terms of 1N and 10P). The main cause of environmental inefficiency was due to nutrient-orientated allocative inefficiency. This finding suggests that the current combinations of inputs were well far away from environmentally optimal mix. More importantly, the improvement in NAE would have significantly stronger impact on the environmental efficiency (e.g. the correlation coefficients of INE with ITE and NAE were 0.34 and 0.94 respectively). The results also show that only 13.5% of farms were operating on the production frontier while only 2% were cost efficient and 1% was environmentally efficient. These indicate that there is great potential to improve both economic and environmental performance of such rice farms. Therefore, farms could achieve higher cost efficiency and environmental efficiency by improving their technical efficiency.

3.2 Costs of Being More Environmentally Efficient

The results showed that about 90% of the total 480 observations have cost efficiency levels which are greater than environmental efficiency levels. This finding clearly shows that cost efficiency deviated from environmental efficiency and that farms in the sample had operated in cost-minimizing rather than environmentally friendly manners. This poses a very important policy implication that agricultural policies should be (re)designed to affect the markets in a way that farms can achieve both economic and environmental efficiency at the same time. Given high governmental subsidies for rice production in South Korea, examples of such policy interventions are to reduce (or remove) subsidies and to impose a tax on nutrient consumption. Table 2 shows the monetary costs of being environmentally efficient as well as the environmental costs of being more cost efficient. The relative changes in the total cost and total consumption of aggregate nutrient were reported in four scenarios: (1) from the current operation to be cost efficient (ICE position), (2) from the current operation to be environmentally efficient (INE position), (3) from the ICE position to the INE position, and (4) from the INE position to the ICE position.

In all regions, the movement from the current operation to the ICE position is associated with reductions in both the total cost and total consumption of nutrients. On average, the movement from the current position to full cost efficiency will reduce 50% of the total costs (equivalent to 959,000 won for the average farm) and 35% of the aggregate nutrient consumption (equivalent to nearly 1,157 kg of EP). This finding suggests that being more cost efficient will also increase environmental efficiency. As shown earlier, improvement in cost efficiency by increasing technical efficiency also enhances environmental efficiency. The movement from the current position to the environmentally efficient operation will obviously reduce the aggregate nutrient consumption (by around 75% of total existing aggregate nutrient consumption) but will be associated with monetary cost (by around 29% of total existing costs). It means that these farms would incur an additional average cost of 2,425 thousand won if they were determined to be environmentally efficient. By doing so, they would reduce the surplus of aggregate nutrients by 2,624 kg of EP that had been sent to the surrounding environment. Hence, the average cost of each EP kg of aggregate nutrient reduction in the balance would be about one thousand won.

The last two columns in Table 2 present the economic (environmental) impacts for the sampled farms to be environmentally (cost) efficient. The movement from the cost efficient position to environmental efficient position will reduce the nutrient use by about 50% but increase the cost by 148% whilst the opposite movement (i.e. INE position to ICE position) will increase the nutrient consumption by 190% but reduce the costs by 35%.

These provide evidence for a trade-off between cost efficiency and environmental efficiency if input and output markets remain business as usual (also without any changes in policy interventions).

Table 2. Farm performance in terms of cost and nutrient use change (%)

Re.	Current to ICE (1)		Current to INE (2)		ICE to INE (3)		INE to ICE (4)	
	Cost	Nutrient	Cost	Nutrient	Cost	Nutrient	Cost	Nutrient
20	-44.60	-36.99	139.59	-78.73	284.16	-53.06	-38.94	295.06
21	-52.97	-37.69	-7.86	-75.62	89.98	-48.17	-33.46	170.76
22	-52.28	-30.77	-16.89	-71.06	82.49	-44.76	-31.94	146.21
23	-51.85	-34.06	25.53	-73.92	159.25	-47.09	-33.93	153.67
24	-51.26	-37.99	29.36	-75.19	58.03	-48.66	-35.67	168.15
25	-56.13	-32.23	0.89	-73.41	125.33	-50.29	-33.84	173.28
26	-50.45	-39.01	29.67	-78.38	151.72	-52.59	-33.56	198.02
27	-55.78	-44.23	3.45	-80.40	136.10	-51.15	-35.01	182.57
28	-42.71	-29.01	18.48	-71.59	109.13	-47.57	-33.01	194.32
29	-42.47	-28.61	75.31	-77.87	200.56	-59.23	-39.69	272.99
Av.	-50.18	-35.01	28.57	-75.25	148.05	-49.68	-34.75	191.17

4. Conclusion

This paper used a DEA estimation technique to estimate and decompose the cost and environmental efficiency of a sample of 96 paddy farms in Kangwon province, South Korea. This empirical study yielded several important findings. First, both production cost and the eutrophying power of these rice farms could be reduced significantly. Improvements in technical efficiency would result in both lower production costs and better environmental performance. Better combinations of inputs would also increase environmental efficiency and this nutrient-orientated allocative efficiency effects on the environmental performance are even stronger than the impacts from improvements in technical efficiency. Second, it is not costless for farms to move from their current operation to the environmentally efficient operation. Third, for those farms which were technically efficient, there were a trade-off between cost and environmental efficiency. These farms could reduce their production costs by choosing cheaper input combinations but at a cost to the water system because by doing so they would also increase the polluting power contained in the balances of N and P. In the same manner, these farms could choose mixes of inputs that contain less eutrophying power but at additional production costs.

These findings also pose several important policy implications. First, without major policy interventions, rice farms could still be able to improve their economic and environmental performance by being more technically efficient. Second, there exist great opportunities for policy makers to intervene into the markets of inputs in order to adjust the prices of inputs so that farms, by minimizing their production costs, also improve their environmental performance. Further investigations on such policy options (such as introduction of taxes on fertilizer uses, removal of subsidies or provision of incentive schemes) are also worth considering.

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