Determinants of Rice Productivity and Technical Efficiency in the Philippines*

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Abstract

Agricultural production determines the efficiency level of households in their farming activities. In the developing countries farmers do not use all potential technological resources, thus making inefficient decisions in their agricultural activities. So, this paper focuses to measure the technical efficiency of rice production and identified determinants of technical efficiency of rice farmers in Philippines. The Loop Survey of the Institute of Rice Research Institute (2007-2012) was analyzed using stochastic frontier production method in the Cobb-Douglas functional form. Result shows that fuel, fertilizer, land rent, planting season, and land area are the factors that affect both production and technical efficiency of rice production. We found mean technical efficiency score of 0.54.

Key words: Food security, technical efficiency, Stochastic Frontier Production, Philippines, Production

1. Introduction

Tropical and semi-tropical Asia contributed 90% of the global rice production. In spite of being produced on small and marginal farms in many of these countries, the production of rice has increased faster than population over the last three decades (Pate and Tan-cruz, 2007; Hossain 2004; Khai and Yabe, 2011). According to Nathan et al; (2013), Southeast Asia produces about 25 percent of global rice output. Rice production has increased by about 18 percent between 2000 and 2010, which is 1.6 percent increase in every year. Rice is the staple food for about 80% of Filipinos, which accounts for 46% and 35% of their caloric intake and protein consumption, respectively. Rice is the single most important agricultural crop in the

Philippines, and is therefore a major source of income for millions of Filipino farmers (Bordey, 2010). The country rank 8th among producers of rice in the world and ironically, it is the world's top rice importer as well. Rice production in the Philippines has increased from 1.16 tons per hectare in 1960 to 3.59 tons per hectare in 2009, which is lower than the previous two years (2007 & 2008) due to damage done by two tropical storms-- namely Ondoy and Pepeng. Typhoons, floods, and droughts caused 82.4% of the total Philippine rice losses from 1970 to 1990 (Lansigan et al. 2000). Fluctuation in domestic rice production has a direct impact on food security, especially for the poorest people of Philippines (Koide et al., 2012).

Philippines's high dependence on rice imports exposes the country to international market shocks and many have serious risk for food security (Dawe et al., 2006; Timmer, 2010). Philippines has reached to its food self-sufficiency goal in 1978, however, it turned into a net importer of rice in 1984 (Umetsu et al. 2003). Achieving self-sufficiency in food grain production is a key development objective in developing countries due to lack of foreign exchange to finance major international purchases. Self-sufficiency in rice is the primary goal of agricultural policy in the Philippines and achieving rice security is directly related to the nation's struggle in eliminating extreme hunger and poverty. An increase in international rice prices, world food crisis in 2008, high prices of agricultural inputs, rising population, natural disasters, increased urbanization, industrial land-use, and decreasing land area in rice been key factors in setting the nation back in its rice-self-sufficiency efforts (Diagne et al., 2013; Pate & Cruz, 2007; Rola, 1990; Timmer, 2010). With a 2% annual population growth rate and a steady increase in per capita rice consumption, imports will likely continue to play an important role in meeting the domestic demand for rice. The Philippine government in 2010 implemented program to support rice self- sufficiency, which mandates to reduce its import by 70% from 2.3 million tons in 2010 to 707 thousand tons in 2011.

On the production side growth and development of rice production have become completely dependent on yield improvements. To meet demand, rice production can be increased either by increasing rice growing area or by improving the efficiency of existing resources allocated to rice production. Yield improvement is governed mainly in two ways; either shifting the yield frontier or by developing and promoting yield-enhancing technologies. Improving rice productivity can contribute to higher yield and in reducing poverty especially in rural areas, increased productivity may also help in increasing the income and food security of small farmers, who depend on rice production for a living. Irrigation, adoption of hybrid and third generation modern inbred rice varieties, training at farmer's level, use of high quality seed, and use of modern agricultural tools can boost rice production in the Philippines (Bordey, 2010). This situation raises the question of how technically efficient rice production in the Philippines, how much production improvement can be made through increased technical efficiency (Pate and Tan-cruz, 2007). To address these questions we analyze the major underlying dimensions of rice productivity and technical efficiency in Central Luzon, district of Philippines, major rice producing area, and evaluate a set of variables that are associated with the productivity. Improving rice productivity can contribute higher production, higher income for farmers, and reduces poverty especially in rural areas.

The major objective of this study is to analyze the factor associated with rice production and factors affecting technical efficiency of rice producers in the Philippines. The production factors are aggregated into six categories, i.e. land, labor, seed, fertilizers, herbicides, and services. The technical efficiency variables are mostly related to managerial and socio-economic characteristics such as farm size, seed cost, fuel cost, fertilizer cost, pesticides cost, operational cost, land rent, irrigation cost, and total labor costs.

2. Literature Review

Battese and Coelli (1992) studied production function of paddy farmers in India and found land and labor cost, and ratio of irrigated land to total land were significant and had a positive relationship with the production of rice. Diagne et al., (2013) studied the production and technical efficiency of rice farmers in the Senegal River Valley. They concluded that production function is affected positively by land, seed, fertilizer and services and negatively by labor costs. They obtained technical efficiency scores in the range of 55% to 60%. They further estimated that fertilizer, herbicides, bird chasing efforts, use of post-harvest technologies such as thresher-cleaner affected the technical efficiency of rice production in Senegal. Tiongco and Dawe (2002) studied the long-term evolution of productivity in Philippine rice farms. They stated that long-term productivity has been stagnant in important rice-growing areas of the Philippines. They concluded that emphasis should be given on crop genetic yield potential to improve productivity and to alleviate poverty from farming system. Use of high yielding varieties during the late 1960s increased the rice production more than doubled from 3.9 million metric tons in 1961 to 9.6 million metric tons in 1990 (IRRI).

3. Data

We use farm-level panel data from the Loop Survey of the International Rice Research Institute (IRRI). This survey began in 1966, and is conducted about once every four years. In this paper we use data from 2007 to 2012. This survey collects farm and household characteristics on individual rice farms over such a long period of time. Loop Survey collects data from two domains of rice farming household. One domain is along a loop of the main highway north of

Metro Manila through the provinces of Central Luzon and the other domain is along a loop through the towns of Laguna. In both domain, double cropping is normal and production systems in these two areas are largely similar. Rice is established by transplanting in both areas. Pesticides use has declined in these areas since the mid-1980s.

4. Methods

Stochastic Frontier Production (SFP) estimation is used in this study. Basically, SFP function estimates the existence of technical inefficiencies of production of firms involved in producing rice. We use fixed-effects Cobb-Douglas and simplified trans-log production functions. To avoid the possibility of multi-collinearity, simplified translog production function is preferred to the standard translog. For the SFP, maximum-likelihood method is applied or the estimation of the parameters of the Cobb-Douglas model and the prediction of the technical efficiencies of the firms over time (Battese and Coelli, 1993). Pitt and Lee (1981) proposed the maximum likelihood estimation of the following Normal-Half Normal SF model

$y_{it}=\alpha + x'_{it}\beta + \epsilon_{it}$,   i=1,….,N,   t=2,…,$T_i$ (1)

$\in_{it}=v_{it} - u_i$

$v_{it} \sim$ N $(0,\sigma^2{}_v)$,

$u_i \sim N^+(0,\sigma^2{}_u)$.

Where y_{it} represents the logarithm of the output of the *i* th firm at the *t* th period of observation, x_{it} is a vector of inputs (production factors and firm-specific variables) associated with the production of the *i* th firm in the *t* th period of observation, β is a vector of unknown parameters. The composed error term $\in_{it}$ is the sum (or the difference) of a normally distributed disturbance, v_{it}, representing measurement and specification error, and a one-side disturbance,

u_i, representing inefficiency. Moreover u_i and v_{it} are assumed to be independent of each other and *iid* across observations.

In the first step, we estimate the specification and estimation of the stochastic frontier production function and the prediction of either the inefficiency effects or the technical efficiencies of the firms. In second stage we performed regression of predicted inefficiency effects or the levels of technical efficiency of the firms with various explanatory variables. Ordinary least squares regression is used to estimate parameters of the second-stage inefficiency model. Schmidt and Sickles (1984) pointed out that the estimation of a SF model with time invariant inefficiency can also be performed by adapting conventional fixed-effects estimation techniques, thereby allowing inefficiency to be correlated with the frontier regressors and avoiding distributional assumption about u_i.

The stochastic frontier production function to be estimated is defined as:

$$\ln Y_{it} = \propto_0 + \sum_k \beta_k \ lnX_{kit} + v_{it} - u_i \quad (2)$$

where the subscripts *i*, *t* and *k* represent respectively farm, year or time and inputs. $\ln Y_{it}$ is the log-transformed rice production value in peso on the farm and t time; $\propto_0$ and β_k are parameters to be estimate. Here, lnX_{kit} is the log-transformed production factors (land, fertilizers, seeds, labor costs, herbicides, and pesticides); v_{it} represents random statistical noise, and $u_i \geq 0$ represents technical efficiency.

Technical efficiency score of farm are estimated by using the following equation:

$$TE_i = \exp(-\hat{u}_i) \quad (3)$$

$$0 < TE_i < 1 \quad (4)$$

Here, TE_i is greater than zero and less than 1.

In the second step, technical efficiency score is used as a dependent variable and regress against factors or independent variables. This regression will then determine the factors affecting TE if rice production in the Philippines. To estimate effects, we use following equation 5,

$$TEffic_{it}=b_0+\beta' Z_{it}+\sigma_{it} \quad (5)$$

where, $TEffic_{it}$ represents the level of technical efficiency; Z_{it} is a vector of variable representing socio-economic characteristics of farmers to explain technical inefficiency.

5. Results and Discussions

Table 1 presents the descriptive statistics of some important variables applied in stochastic frontier production model and some farm specific characteristics. The average Filipino rice farmer operates about 1.22 ha ranging farm area from 0.1 to 4.8 hectares, suggesting a significant variability in farm sizes among rice farmers. The total value of farming retained by the farmer after harvest is about averagely 109.02 cavan. With the expectation of higher return from rice farming, Filipinos farmers spend significant amount of money on fertilizer, about on 10,902 peso per season. Rice planting season is a dummy variable representing 0 for wet season and 1 for dry season.

Cobb-Douglas production function was estimated using the maximum likelihood method. The parameters estimates and other tests are presented in table 3. Result shows that the cost of fertilizer is a positive and statistically significant in explaining rice production in Philippines at 10% significance level. Total acreage is also positive and significant factor indicating that a 1% increase in acreage increases rice production by 0.48%. The coefficient on a dry season, dummy variable, positive and is significant at the 10% level of significance. Fuel cost as a part of production function is also significant at the 5% level. The insignificant coefficient for herbicide use in our result may be due to the fact that weed and pest control is not a productive input, but rather a damage abatement input which does not directly affect productivity, but indirectly through technical efficiency. Our results are consistent with research conducted by Diagne et al. (2013) and Tiongco and Dawe (2001).

Technical efficiency (TE) of a given firm is as the ratio of its mean production to the corresponding mean production if the firm utilized inputs most efficiently. In simple words, technical efficiency refers to a firm's ability to achieve maximum output from a given bundle of inputs. The mean TE score for our sample was 0.548 obtained through the fixed-effects model and ranged from 46% to 74%. The results showed that farmers in Philippines can increase production by 46% in the existing technological conditions. Diagne et al. (2013) found 0.55 as the mean technical score for Senegal rice production. TE score is consistent with findings in the literature. In the second-stage analysis, the logistic transformations of the TE scores, obtained through Cobb-Douglas production function were regressed on the production factors and a set of farm characteristics, results are reported in table 4. Fertilizer cost is negative and statistically significant, indicating a 1% in total fertilizer cost, reduces technical efficiency by 2.85%. A possible explanation is that rice farmers will purchase less fertilizer with increased fertilizer price and that in turn will lead to application of fertilizers and eventually decreases in technical efficiency of the rice production. The coefficient on rice production value, in peso, is positive and significant at the 1% level of significance, indicating that a 1% increase in value of produced rice, increases technical efficiency by 26.3%. On the other hand, with a 1% increase in fuel cost, reduces technical efficiency by 0.17%. Similarly, with a 1% increase in land rent reduces, technical efficiency by 11.7%. This is likely due to the fact that farmers need to pay significant amount for land rent in Philippines. Compared to wet season, planting in dry season reduces technical efficiency of rice production by 8%. Generally rice is planted in wet season. Some farmers plant rice in dry season if they have good provision of irrigation resources. With a 1%

increase in cultivated rice area, technical efficiency scores decreases by 9.82%. This is likely due to farmers are unable to manage more farmers due to lack of resources and unavailability of labor. Variable such as seed cost, pesticides cost, labor cost, operational cost does not play any significant role in the technical efficiency of rice production.

6. Conclusion

Agriculture is main source of income in developing countries and increased agricultural productivity has the potential to alleviate poverty of the farmers. Improvements in agricultural productivity are a topic of high importance in these countries. Agricultural farms in developing countries are heterogeneous, while some farmers may be commercialized but many are still practicing traditional agricultural systems. After fifty years of the Green Revolution, the Philippines continue to struggle to produce for sufficient rice to feed its population. Food security is a major problem in Philippines and largely affected from farmer's production decision and technical efficiency of rice production. This study attempted to estimate technical efficiency of rice farmers and to identify its determinants. This study also examined the relationship of the various attributes with the technical efficiency of farmers.

Land area, planting season, fuel cost, fertilizer cost, and land rent have positive significant relationship with the value of rice production in Philippines. Our analysis estimated the TE level of Filipino rice production to be 54.6 percent, which is lower than other studies in the literature, especially when it comes to developing countries. TE scores are affected negatively by price of fuel, fertilizers, and land rent. However our study found that rice production, in peso, has positive and significant relationship with the technical efficiency of rice production in Philippines. Finally, Fuel cost, fertilizer cost, land rent, time of planting, and land area affects both levels of productivity and technical efficiency levels of rice farmers in the Philippines.

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Table 1. Descriptive Statistics of the variable used in the model (2007-2012)

Variable	Description	Mean	St. Dev	Min	Max
Production	Total production+	109.020	73.324	8	600
Land	Land in hectares	1.225	0.719	0.1	4.8
Output value	Total value of rice production in peso	79439.42	63011.34	5400	537600
Seed	Total seed cost *	3397.652	2934.193	0	18000
Fuel	Total fuel cost*	2191.365	3603.509	0	26840
Fertilizer	Total fertilizer cost*	10902.07	7541.925	0	45800
Pesticide	Total cost of all pesticides*	1733.646	1570.552	0	9250
Labor cost	Total labor cost in land preparation*	1939.687	1916.051	0	12550
Operational	Farm operational costs*	5798.869	4913.537	0	32672.4
Land rent	Land rental costs*	3761.368	6623.472	0	44800
Irrigation	Total irrigation costs*	899.737	1502.218	0	10000
Price per kg	Price of rice per kg (peso/kg)	13.368	2.562	6	20
Season	Planting season	0.402	0.491	0	1

*unit of cost is peso (1 peso=$0.023)
+yield in cavan (1 cavan=60 kg)

Table 2. Stochastic frontier production estimates

Variables	Coefficient	t-statistics
Constant	6.655***	6.22
Log of land in ha	0.485***	5.12
Planting season	0.401***	6.84
Log of seed cost	0.0649	1.16
Log of fuel cost	0.00728*	2.04
Log of fertilizer cost	0.130**	2.62
Log of pesticides cost	0.00817	1.46
Log of all labor cost	0.00160	0.25
Log of operational cost	0.0115	1.09
Log of land rent cost	0.285***	4.34
Log of irrigation cost	0.00265	0.74
μ	0.605	0.71
η	-0.0103	-0.23
σ	-2.445***	-17.28

$^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$

Table 3. Determinants of technical efficiency of rice production in Philippines

Variables	Coefficient	t-statistics
Constant	-1.804***	-8.31
Log of price per kg	-0.0204	-0.44
Log of land in ha	-0.0982***	-3.67
Log of production in peso	0.263***	10.35
Log of seed cost	-0.0259	-1.93
Log of fuel cost	-0.00176*	-2.26
Log of fertilizer cost	-0.0285*	-2.54
Log of pesticides cost	-0.00115	0.83
Log of total labor cost	0.00125	0.83
Log of operational cost	-0.00213	-0.87
Log of land rent	-0.117***	-8.33
Log of irrigation cost	0.000254	0.32
Planting season	-0.0792***	-4.40

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$