Impact of Land Ownership on Productivity and Efficiency of Rice Farmers: A Simulated Maximum Likelihood Approach

Krishna H. Koirala
32 Martin D. Woodin Hall
Dept. of Agricultural Economics and Agribusiness
Louisiana State University
Baton Rouge, LA 70803
E-mail: kkoiral@tigers.lsu.edu

Ashok K. Mishra
Professor
128 Martin D. Woodin Hall
Dept. of Agricultural Economics and Agribusiness
LSU, Baton Rouge, LA 70803
Phone: (225) 578 0262; Fax: (225) 578 2716
E-mail: amishra@lsu.edu

&

Samarendy Mohanty
Head, Social Sciences Division
International Rice Research Institute
Laguna, Philippines
E-mail: s.mohanty@irri.org


Copyright 2014 by Koirala, Mishra, and Mohanty. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.
Impact of Land Ownership on Productivity and Efficiency of Rice Farmers: A Simulated Maximum Likelihood Approach

Abstract
This paper investigates the factors affecting rice production and technical efficiency of rice farmers in Philippines. Particular attention is given to the role of land ownership. We use the 2007-2012 Loop Survey from the Institute of Rice Research Institute (IRRI) and simulated maximum likelihood (SML) approach. Results show that land ownership plays an important role in rice production. In particular, compared to owner operators, farmers who lease land are less productive. Additionally, result shows that land area, irrigation and labor cost are significant factors affecting rice production. We found mean technical efficiency score of 0.82. Finally, educated females, farmers leasing land and dry season farming tend increase technical inefficiency.

Keywords: Simulated maximum likelihood, land ownership, technical efficiency, Philippines, rice production

Introduction
Agriculture is main source of income in many developing countries and increased agricultural productivity has the potential to increase farming income and alleviate poverty in rural areas. 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). Rice Production has tripled in between 1970 to 2008 from 5.32 million metric tons to 16.82 million tons in the Philippines; however production declined to 15.77 million metric tons in 2010 due to strong typhoons¹. In 2011, rice production in Philippines gained remarkable improvement and

production rose to 16.68 million metric tons. Rice is the Philippines’ staple food. Filipino meal cannot be complete without it. Rice expenditure shared a 20% of an average Filipino household’s food expenditures.\(^2\) Rice is both a source of income as well as major expenditures for many households in the Philippines.

Literature (Diagne et al., 2013; Pate & Cruz, 2007; Rola, 1990; Timmer, 2010) points out several factors, such as world food crisis in 2008, high prices of agricultural inputs, limitations on land ownership, rising population, may be associated with setting the Philippines back in its rice-self-sufficiency efforts—resulting in higher rice imports. Philippines’s high dependence on rice imports exposes the country to international market shocks and may have serious risk for food security (Dawe et al., 2006; Timmer, 2010). Self-sufficiency in rice is the primary goal of agricultural policy in the Philippines; achieving rice security is directly related to the nation’s struggle in eliminating extreme hunger and poverty. Finally, the Philippine government in 2010 implemented program to support rice self-sufficiency, which mandates to reduce its import by 70 percent from 2.3 million tons in 2010 to 707 thousand tons in 2011.

Agricultural farms in Philippines are heterogeneous. On one hand you have small group of farmers who operate large farms; on the other hand, many farmers operate small subsistence farms, large majority are still practicing traditional agricultural systems. Land resource in the Philippines is the major limiting factor in rice production. The Philippines’ area that harvests rice is very small (4.46 million hectares in 2008) compared with major rice-producing countries in Asia. India has 44 million hectares, China has 29.49 million hectares, Indonesia has 12.31 million hectares, and Thailand has 10.25 million hectares rice cultivated land. According to

International Rice Research Institute (IRRI), three main factors that make the Philippines remain dependent on other countries for rice supply are limited land area, increasing population growth, and constructing new infrastructure.

Land rental market is an important institution in Filipino agriculture. Various land reforms have stipulated that no more than seven hectares of land could be owned. Additionally, under the Comprehensive Agrarian Reform Law of 1988, any form of transfer of the land awarded under the Comprehensive Agrarian Reform Program (CARP) is prohibited. Gordoncillo (2012) reported that CARP is a major intervention to effect rural development in the Philippines which was instituted in 1988 and its implementation is extended until 2014. This reform program mandates that all lands exceeding seven hectares are bought by the government and sell to the landless farmers. CARP covers all private and public agricultural lands regardless of commodity produced and tenurial status. The primary objectives of this program are to improve equality and the increase in productivity and growth in the rural areas. The CARP can have adverse effects on the efficiency of the land rental market (Ballesteros and Bresciani, 2008). It constrains rental activity due to the possibility that leasing of awarded lands under CARP could lead to rental disputes and or cancellation of awarded rights to land—perhaps resulting in higher land rental rates.

Therefore, with increasing population—2 percent projected annual population growth rate—and land loss due to natural disasters, land rental market will likely put an upward pressure on land rental rates. With self-sufficiency goal in mind, higher rental rates for land could result in a loss of rice productivity and technical efficiency. Therefore, this study attempts to address the factors associated with rice production and factors affecting technical efficiency.
(TE) of rice producers in the Philippines. Particular attention is given to land ownership and estimation method.

**Literature Review**

There have been many previous studies of rice productivity and technical inefficiency of rice production in the developing countries. The frontier production function was used to measure technical efficiency which was first used by Farrell (1957). 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. Abedullah and Mushtaq (2007) studied technical efficiency of rice production in Pakistan and found that farm mechanization (tractor) played a significant role to improve farmer’s technical efficiency. 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 percent to 60 percent. 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.

Dawson and Lingard (1989) studied farm efficiency over time on Philippine rice farms and concluded that technical inefficiency is the major reason for deviation from the frontier production function. Villano and Fleming (2006) studied technical inefficiency and production risk in rice farming in the Philippines and found 79 percent average technical efficiency scores of the firms using eight year panel data. They concluded that age and education of farm operators, ratio of adults in the farm households and off-farm income have significant impact on the technical inefficiency of rice production in the rainfed lowland environment. 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).

Umetsu et al., (2003) studied regional differences in total factor productivity, efficiency, and technological change in the Philippine rice sector using Malmquist productivity indices. They found that negative productivity growth during the early 1970s, followed by positive growth and again negative growth in the late 1980s. They further found that certain regions such as Central Luzon, Western Visayas, and Southern and Northern Mindanao had higher rates of technological changes than others. Mariano et al., (2011) studied technical efficiency of rice farms in different agroclimatic zones in the Philippines using stochastic metafrontier model and found that area, seeds, fertilizer, pesticides, labor, and machine cost are determining factor for rice productivity and age, education, experience, training, non-rice income, household size are driving factor for technical efficiency of rice production. Khai and Yabe (2011) studied the technical efficiency analysis of rice production in Vietnam and found that irrigation, education, and labor force have positive and significant impact to the technical efficiency.

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.

Table 1 presents the descriptive statistics of inputs and farm specific variables to estimate
stochastic frontier production model using SML. The average Filipino rice farmer operates 1.24
hectares, ranging from 0.1 to 4.8 hectares, suggesting a significant variability in farm size. The
total value of farming retained by farmers after harvest is about 80,828 peso. With the
expectation of higher returns from rice farming, Filipinos farmers spends a significant amount of
money on fertilizer, about 11,077 peso. As an input they used fuel, fertilizer, pesticides, capital,
labor, and land areas. Farm specific variables include planting season, sex and age of operator
and educational attainment of male and female, and household size. Average age of male headed
household is 59 years, higher than female headed households, 55. Average educational
attainment of males is higher than females. Finally, average household size is 5.

Econometric Model

Technical efficiency is an important topic studied in agricultural production because of
policy decision and firms’ ability to use input mixes in the most efficient manner to produce the
maximum output. Two methods have been proposed to determine the technical efficiency of a
firm: parametric and non-parametric. The parametric approach assumes the production
functional form a priori estimation of the data; however the non-parametric approach uses the
data to determine the functional form. In this paper we used the parametric approach to estimate
technical efficiency.
**Stochastic Frontier models**

The stochastic production function is a parametric analysis that has been commonly used to estimate technical inefficiencies. The stochastic frontier production shows the most efficient use of inputs to produce the maximum output. The stochastic frontier regression model is a linear regression model having nonnormal asymmetric disturbance. It was originally developed by Aigner, Lovell, and Schmidt (1997) and Meesuen and van den Broeck (1997).

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

\[
\ln Y_{it} = \alpha_0 + \sum_k \beta_k \ln X_{kit} + \nu_{it} - u_i \tag{1}
\]

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; \(\alpha_0\) and \(\beta_k\) are parameters to be estimate. Here, \(\ln X_{kit}\) is the log-transformed production factors (land, fertilizers, seeds, labor costs, and fuel); \(\nu_{it}\) represents random statistical noise, and \(u_i \geq 0\) represents technical efficiency.

**Simulated Maximum Likelihood**

A random variable \(u_i\) is of particular interest which is a measure of the percentage by which the particular observation fails to achieve the frontier, idea production rate (Greene 2003). The firm-specific technical efficiency parameter, \(u_i\), takes the value of zero for a technically efficient firm and one for the technically inefficient firm (Kalirajan and Shand, 1989). There are four distributional frameworks for inefficiency component; normal-half normal \(u \sim N[0, \sigma_u^2]\), normal-exponential \((u \sim \text{exponential with parameter } \theta)\), truncated normal, and normal-gamma \((u \sim \text{gamma with parameters } \theta \text{ and } P)\). However, except normal-gamma, none of these distributions imply that observations in the sample are concentrated near zero inefficiency (Khitarishvili 2002). The primary advantage of gamma distribution is that it does not require the firm-specific inefficiency measures be predominately near zero (Greene 1990). The distribution
of inefficiency can move away from zero in gamma distribution. A simulated maximum likelihood considers $u_i$ has flexible two-parameter gamma distribution. This model is more flexible than the normal or exponential model.

The normal-gamma stochastic frontier model is an extension of the normal-exponential proposed by Green (1990), Beckers and Hammond (1987), and Stevenson (1990). The gamma distribution has following distributional assumptions:

(i) $V_i \sim iid \ N(0, \sigma_v^2)$.
(ii) $u_i \sim iid$ gamma.
(iii) $V_i$ and $u_i$ are distributed independently of each other, and of the regressors.

Gamma distribution has the probability density function which can be defined as $u \sim G(\theta, p)$:

$$f(u) = \frac{\theta^p}{\tau(p)} u^{p-1} e^{-\theta u}, \ u \geq 0, \theta, p > 0$$  \hspace{1cm} (2)

where, $\theta$ is the scale parameter and $p$ is the skewness parameter. The gamma distribution is a two parameter distribution depending up on $p$ and $\theta$. Inefficiency term has exponential distribution for values of $p$ between 0 and 1. With these values, mass of the distribution is still concentrated near zero. Distribution of disturbances is concentrated at a point away from zero for values of $p$ greater than 1 (Greene 1990).

According to Green (2003), the log likelihood function for the normal-gamma model is actually the expectation of a random variable which can be simulated. Thus, the normal-gamma model is estimated by the method of simulated maximum likelihood. The simulation is carried out using Halton draws. Halton draws speed up the process of maximization by simulation.

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

$$TE_i = \exp (-\hat{u}_i)$$  \hspace{1cm} (3)

$$0 < TE_i < 1$$  \hspace{1cm} (4)
Here, $TE_i$ is greater than zero and less than 1. In our model we used technical inefficiency as a dependent variable which is regress against socio-economics and farm specific factors. This regression will then determine the factors affecting technical inefficiency of rice production in the Philippines. To estimate effects, we use following equation 5,

$$TE_{i} = b_{0} + \beta'Z_{i} + \sigma_{i}$$

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

Results

A Cobb-Douglas production function was estimated using the simulated maximum likelihood method. We applied pooled OLS to estimate parameters, which are reported in table 2. The estimated signs of the parameters are as expected. An increase in the quantity of input leads to an increase in quantity of output produced which implies a consistent of production function results with production theory. Significant inputs include: labor, size of land, and land rent and ownership of farm. For example, the coefficient of labor (total labor) has a positive and significant impact on output, indicating that a 1% increase in the cost of labor increases value of rice output by 0.5%. Similarly, the coefficient of farm size (land) has a positive and significant impact on output, indicating that a 1% increase in the size of farm increases value of rice output by about 0.4%.

Result shows that the cost of irrigation has a positive and statistically significant effect on rice production, at the 10% level of significance. Finally, results in table show that farm operators who lease the land for farming have lower value of rice output. Findings here are consistent with theory. Empirical evidence suggests that farmers who lease land for farming are less likely to invest in land improvement activities (Abdulai, Owusu, and Goetz, 2011).
lack of security and absence of sufficient incentives for and returns from investment, farms operated by lessors may run inefficiently (Otsuka and Hayami, 1988).

Importantly, based on the estimated production function, we have calculated technical efficiency score of the rice farmers in Philippines. Technical efficiency (TE) of a given firm is the ratio of its mean production to the corresponding mean production if the firm utilized inputs most efficiently. However, we are interested in knowing which factors affect technical inefficiency. This can be calculated by subtracting as: 1-TE. Figure 1 shows a kernel density estimate of the underlying density of the technical inefficiency in rice farming in Philippines. We find mean technical inefficiency = 0.18 with standard deviation of 0.12. Inefficiency ranged from 5 percent to 86 percent. The mean TE score for our sample was 0.82 (82%) indicating that rice farmers in Philippines can increase production by 12% with existing technology. Findings here are comparable to the findings of Khai and Yabe (2011) who found TE score of 82 percent in Vietnam rice production—however, they used cross-sectional data in their study. On the other hand, Diagne et al., (2013) who used longitudinal data from Senegalese rice farmers, found 0.55 (55%) mean technical score for rice production.

In the second-stage analysis, technical inefficiency scores, obtained through Cobb-Douglas production function were then regressed on socio-economic variables and farm specific characteristics. Result is reported in table 4. Results indicate that rice grown in dry season tend to increase TE inefficiency by 0.06 compared with other seasons. This is mainly due to lack of water and irrigation facilities in dry season. Recall 70 percent of farmers grow rice in dry season compared with other seasons mainly due to lack of irrigation facilities. Female education affect to the technical inefficiency of rice farming in Philippines. A plausible explanation for this may be that male members of the household make farming decisions and while females members tend
to work off the farm. Additionally, females tend to have higher education—leading to a greater probability of working off the farm (Esudillo, Quisumbing, Otsuka, 2000). Finally, results in table 3 indicate that farmers who lease their land (lessors) for rice farming tend to have higher technical inefficiency. Increase in lessor operators increases technical inefficiency by 0.03 percent.

**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 is 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 continues to struggle to produce 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 rice production function using recent (2007-2011) longitudinal data from Philippines. Particular attention was given to the role of land ownership. Finally, the study also examined the relationship between of the various attributes and technical efficiency of Filipino rice farmers.

An interesting finding from this study reveals that leased rice farms tend to have lower value of rice production. Further, farms operated under leased ownership tend to have higher technical inefficiency. Our analysis shows that the TE level of Filipino rice production is about 82 percent—still room for improvement under current method and technology. Technical inefficiency scores tend to increase with female education, leasing farm operators and rice farming in dry season.
References


Mariano, Marc Jim, Renato Villano, Euan Fleming, and Rachelle Acda. "Meta frontier analysis of farm-level efficiencies and environmental-technology gaps in Philippine rice farming."


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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Mean</th>
<th>St. Dev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>Land in hectares</td>
<td>1.241</td>
<td>0.737</td>
<td>0.1</td>
<td>4.8</td>
</tr>
<tr>
<td>Output value</td>
<td>Output of rice production in peso</td>
<td>80827.94</td>
<td>64272.45</td>
<td>5400</td>
<td>537600</td>
</tr>
<tr>
<td>Seed</td>
<td>Total seed cost *</td>
<td>3440.78</td>
<td>2967.261</td>
<td>0</td>
<td>18000</td>
</tr>
<tr>
<td>Fuel</td>
<td>Total fuel cost *</td>
<td>2248.083</td>
<td>3607.586</td>
<td>0</td>
<td>26840</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>Total fertilizer cost*</td>
<td>11076.88</td>
<td>7815.148</td>
<td>0</td>
<td>45800</td>
</tr>
<tr>
<td>Labor cost</td>
<td>Total labor cost *</td>
<td>21660.05</td>
<td>18798.69</td>
<td>1532.4</td>
<td>160790.6</td>
</tr>
<tr>
<td>Capital</td>
<td>Land rental value*</td>
<td>3701.21</td>
<td>6587.605</td>
<td>0</td>
<td>44800</td>
</tr>
<tr>
<td>Male age</td>
<td>Male age in years</td>
<td>58.592</td>
<td>12.710</td>
<td>24</td>
<td>91</td>
</tr>
<tr>
<td>Male edu</td>
<td>Male education in years</td>
<td>8.570</td>
<td>3.263</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Female age</td>
<td>Age of female household in year</td>
<td>54.6411</td>
<td>12.1881</td>
<td>21</td>
<td>87</td>
</tr>
<tr>
<td>Female edu</td>
<td>Female education in years</td>
<td>7.960</td>
<td>3.286</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Size</td>
<td>Household size</td>
<td>5.343</td>
<td>2.228</td>
<td>2</td>
<td>13</td>
</tr>
</tbody>
</table>

*unit of cost is peso (1 peso=$0.023)
Table 2. Simulated Maximum Likelihood estimation

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>t-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Index Equation for Model</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>5.817**</td>
<td>13.638</td>
</tr>
<tr>
<td>Log of seed cost (Peso)</td>
<td>0.007</td>
<td>0.345</td>
</tr>
<tr>
<td>Log of fuel cost (Peso)</td>
<td>0.006</td>
<td>1.116</td>
</tr>
<tr>
<td>Log of fertilizer cost (Peso)</td>
<td>0.031</td>
<td>1.464</td>
</tr>
<tr>
<td>Log of pesticide cost (Peso)</td>
<td>0.016</td>
<td>1.343</td>
</tr>
<tr>
<td>Log of total labor cost (Peso)</td>
<td>0.500**</td>
<td>12.200</td>
</tr>
<tr>
<td>Log of land rent (Peso)</td>
<td>0.014**</td>
<td>2.588</td>
</tr>
<tr>
<td>Log of land (hectares)</td>
<td>0.396**</td>
<td>7.587</td>
</tr>
<tr>
<td>Log of irrigation cost (Peso)</td>
<td>0.010*</td>
<td>1.938</td>
</tr>
<tr>
<td>Leasing operators</td>
<td>-0.144**</td>
<td>-2.806</td>
</tr>
<tr>
<td>Share tenant operators</td>
<td>-0.079</td>
<td>-0.870</td>
</tr>
</tbody>
</table>

**Variance parameters for compound error**

| Theta                     | 6.243**     | 1.633       |
| P                        | 0.962       | 0.762       |
*represents variables are significant at 10 percent level of significance
**represents variables are significant at 5 percent level of significance

Figure 1. Distribution of inefficiency over all farms
### Table 4. Determinants of rice farming inefficiency in Philippines

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>t-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.004</td>
<td>0.84</td>
</tr>
<tr>
<td>Male education (years)</td>
<td>0.0001</td>
<td>0.83</td>
</tr>
<tr>
<td>Male age (years)</td>
<td>0.0005</td>
<td>0.908</td>
</tr>
<tr>
<td>Female education (years)</td>
<td>0.003**</td>
<td>2.344</td>
</tr>
<tr>
<td>Female age (years)</td>
<td>0.0002</td>
<td>0.366</td>
</tr>
<tr>
<td>HH size (number)</td>
<td>0.0002</td>
<td>0.116</td>
</tr>
<tr>
<td>Regional dummies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulacan</td>
<td>0.004</td>
<td>0.144</td>
</tr>
<tr>
<td>Nueva</td>
<td>-0.001</td>
<td>-0.059</td>
</tr>
<tr>
<td>Pangasin</td>
<td>0.014</td>
<td>0.421</td>
</tr>
<tr>
<td>Tarlac</td>
<td>0.021</td>
<td>0.573</td>
</tr>
<tr>
<td>Dry season dummy</td>
<td>0.067**</td>
<td>7.013</td>
</tr>
<tr>
<td>Land ownership</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leasing operators</td>
<td>0.025**</td>
<td>2.539</td>
</tr>
<tr>
<td>Share tenant operators</td>
<td>0.012</td>
<td>0.549</td>
</tr>
<tr>
<td>Irrigation dummies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump irrigation</td>
<td>0.0221</td>
<td>1.390</td>
</tr>
<tr>
<td>Irrigated farm</td>
<td>0.0175</td>
<td>1.293</td>
</tr>
</tbody>
</table>

**represents variables are significant at 5 percent level of significance