Analyzing the Technical Efficiency of Rice Farmers in the Dominican Republic

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I Introduction

Rice is the staple food in the Dominican Republic (DR) and one of the leading crops on social and economic importance in many rural communities. In 2009, the agricultural sector’s contribution to the Dominican gross domestic product (GDP) was 7.7 % while rice accounted for 0.5 % of the GDP (Banco Central, 2010). At the same time, rice is being cultivated on over 140,000 hectares every year by more than 30,000 farmers across the county, providing employment for over 250,000 workers (Moquete, 2004). Further, it is one of the main sources of protein intake along with beans in the national diet and consumers expend 13% of their total food expenditure on rice (Ministry of Agriculture, 2009).

Recently, rice production can be considered as a relative success story. Total area harvested along with total production have been increasing, from 98,000 hectares in 1990 to 182,000 hectares in 2009 and from 277,000 tons in 1990 to 552,000 tons in 2009. In addition, since 2005 up to date the country has been reaching over 90% rice self-sufficiency and even exporting small amounts (Ministry of Agriculture, 2009). Nonetheless, some farmers’ leader suggests that this achievement to date does not contribute so much in raising the living standards of rice farmers. In spite of this, perspectives on rice sector viability are highly questionable since rice market will be liberalized in 2025 under the Dominican Republic, Central America and United States of America Free Trade Agreement (DR-CAFTA) framework. Under this FTA, US rice farmers, who produce at a relative low cost, will be able to export to the DR duty-free.

With the aim to increase productivity, the Dominican Institute for Agricultural, Livestock, and Forestry Research (IDIAF in Spanish) has developed several high yielding rice varieties, which with favorable environmental conditions and appropriate management can significantly lead to higher level of output than existing varieties; for instance, yields from 7 to 8 tons/ha compared to 4 to 4.6 tons/ha (paddy rice basis). However, there is a gap between the yield obtained at experimental extensions and actual farm yield, which may be explained by biological constraints, relative costs and returns, socio-economic factors, institutional constraints, and deficiencies in the management practices of farmers.

On one hand, it is important to raise rice productivity in order to attain high level of self-sufficiency and improve the sector’s competitiveness since the country is under an FTA. Improving productive efficiency of rice farmers positively influences the sector’s competitiveness since available resources and technology might be used more efficiently. There are basically two approaches to address these challenges: improve production efficiency and/or introduce new technologies. The later one is associated with new costs, and therefore it might be more cost effective to increase farm production by concentrating on improving farm level efficiency. This indicates that farm production can be increased with the current set of inputs and the given technology.
Therefore, attention to empirical estimation of farm level technical efficiency (TE) must be given. However, to the best of our knowledge, there is only one study on productive efficiency analysis of crops in the DR. Therefore, the objectives of this paper are to estimate the possibilities for productivity gains by improving the efficiency of rice farmers and to identify rice farmer/farms socio-economic factors associated with efficiency.

II Study Site, Data and Analytical Framework

This study employs farm level data collected on March 2008 in Monte Cristi province, northwest of DR. In this province, agriculture plays a key role in the local economy, mainly producing rice, which shares 17% of the total area under cultivation nationwide (Ministry of Agriculture, 2009). A total of 93 rice farmers were randomly selected within this province. Data was collected through a face to face interview using a structured questionnaire, including information on farm size, production cost, output, source of credit, contact with extension service staff, schooling, etc.

Stochastic frontier production models and data envelopment analysis are the most common used methods to measure TE in the productive efficiency analysis literature. The stochastic frontier production models have a composed error with a two-sided symmetric term that captures random effects outside of the control of the farmer (weather, pest, disease, luck, etc.) and a one-sided component that accounts for inefficiency. This is a desirable feature when analyzing farm level data from developing countries, where data may include some measurement errors given that the keeping of accurate records is not always a priority for small holding farmers. The stochastic frontier production function model is specified as following:

\[
\ln Y_i = \ln \beta_0 + \sum_{j=1}^{4} \beta_j \ln X_{ij} + \nu_i - u_i
\]

Where \( Y_i \) is rice yield of the \( i \)-th farm in fanega\(^1\)/tarea\(^2\), \( \beta_0 \) is the intercept and \( \beta_j \) are response parameters to be estimated or elasticity corresponding to each input \( (i = 1, \ldots, 4) \), \( \ln \) is the natural logarithm, \( X_{ij} \) is pesticides (plant protection) expenses in RD$/tarea, \( X_{3i} \) is fertilizer expenses in RD$/tarea, \( X_{4i} \) is labor expenses in RD$/tarea, \( X_{4i} \) is hired machinery services expenses in RD$/tarea, \( \nu_i \) is a symmetrical two sided normally distributed random error that captures the stochastic effects outside the farmer’s control, measurement errors, and other statistical noise. It is assumed to be independently and identically distributed with zero mean and variance, \( \sigma^2 \), and independent of \( u_i \). While \( u_i \) is a non-negative random variable that captures the technical efficiency of the \( i \)-th farmer and assumed to be independently distributed as truncation (at zero) of the normal distribution with mean \( \mu \) and variance, \( \sigma^2 \), \( \sigma^2 \). This study assumed linear functional form and this distributional specification following Battese et al. (1996), Shehu et al. (2007) and Idiong (2007) and because it allows for a wider range of distributional shapes. The term \( u_i \) is defined by:

\[
u_i = \delta_0 + \sum_{j=1}^{5} \delta_j Z_{ij}= \delta_0 + \sum_{j=1}^{5} \delta_j Z_{ij}
\]

Where \( \delta_0 \) is the intercept term and \( \delta_j \) is the parameter for the \( j \)-th explanatory variable, \( Z_{ij} \) is source of land, i.e. if \( Z_{i1} = 1 \) then the farmer is an agrarian reform beneficiary and zero otherwise, \( Z_{i2} \) is farm size, i.e. if \( Z_{i2} = 1 \) for medium-size farms (35 and 100 tarea) and zero otherwise, \( Z_{i3} \) is education, i.e. if \( Z_{i3} = 1 \) then the producer has 6 or more years of schooling and zero otherwise, \( Z_{i4} \) is credit, i.e. if \( Z_{i4} = 1 \) farmer borrow money from rice sector moneylenders and zero otherwise, \( Z_{i5} \) is contact with extension staff, i.e. if \( Z_{i5} = 1 \) farmer has contact with extension service and zero otherwise. The maximum likelihood (ML) estimates for all parameter of the stochastic frontier production and inefficiency model specified by equations 1 and 2 were simultaneously estimated.
estimated using the program, FRONTIER 4.1 (Coelli, 1996). This program also estimated the variance parameter in terms of parameterization:

\[ \sigma^2 = \sigma_u^2 + \sigma_v^2 \]  

\[ \gamma = \frac{\sigma_u^2}{\sigma^2}; 0 \leq \gamma \leq 1 \]  

The parameter gamma (\( \gamma \)) indicates the share of inefficiency in the overall residual variance and lies between zero (0) and one (1). The technical efficiency of a farmer at a given period of time is defined as the ratio of observed and frontier output, which is embedded in \( u_i \) (eq. 5), when \( u_i = 0 \), production is on the frontier and the farm is technically efficient, but if \( u_i > 0 \), then the farm is inefficient, since production lies below the frontier.

\[ TE = \frac{Y_i}{Y^*_i} = \exp(-u_i) \]  

1) 1 fanega = 100 kilograms of paddy rice;  
2) 1 acre = 6.15 tarea; 1 tarea = 0.16 acres; 1 tarea = 0.064 ha.

### III Results and Discussion

The ML estimates of the parameters in the stochastic frontier are presented in table 1. The estimated coefficients for pesticides, labor, and hired machinery services expenses variables of the stochastic frontier had the expected positive signs and were statistically significant at 10%, 1% and 1% level, respectively, indicating that all the variables included in the model have a positive relationship with rice yield and therefore higher yield would be attained from additional quantities use of these variables, ceteris paribus. This increase in rice yield could be the result of a better land preparation, better weeding, manual land leveling and other cultivation practices because rice farming relies on hired machinery services for land preparation and harvest; at the same time, rice cultivation is labor intensive in the DR. The estimated coefficient on fertilizers expenses was statistically insignificant, suggesting that fertilizer do not affect the yield of rice significantly. The gamma value was 0.99 and highly statistically significant at 1% level, indicating that most of the variation in rice yield is attributed to differences in farming practices rather than random variability. This also implies that the Cobb-Douglas stochastic production frontier is an adequate representation of the data. The likelihood ratio test indicates that the rice farmers in Monte Cristi province were not fully technical efficient. The likelihood ratio test indicates that the rice farmers in Monte Cristi province were not fully technical efficient (\( \chi^2 = 20.85 > \chi^2_{(1, \gamma)} = 17.755 \)). In turn, sigma-square was 1.13 and significant at 10%, indicating the correctness of the specified assumptions on the distribution of the composite error term.

The ML estimates for parameters of the inefficiency model are presented in table 2. The coefficient of source of land was estimated to have a statistically non-significant negative effect upon the inefficiency effects. This
suggests that to be an agrarian reform beneficiary is directly related with productivity. This is in agreement with the work of Bravo-Ureta and Pinheiro (1997), who analyzed productive efficiency of crops in the DR. An underlying factor might be that agrarian reform beneficiary farmers have better access to training and technical information since the Agrarian Reform Institute assigns technicians to assist farmers.

Table 2 ML estimates for parameters of the inefficiency model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameters</th>
<th>Coeff.</th>
<th>Std. errors</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>δ₀</td>
<td>-7.45</td>
<td>4.51</td>
<td>-1.65*</td>
</tr>
<tr>
<td>Source of land</td>
<td>δ₁</td>
<td>-0.09</td>
<td>0.14</td>
<td>-0.63ns</td>
</tr>
<tr>
<td>Farm size</td>
<td>δ₂</td>
<td>-0.08</td>
<td>0.14</td>
<td>-0.61ns</td>
</tr>
<tr>
<td>Education</td>
<td>δ₃</td>
<td>-1.05</td>
<td>0.55</td>
<td>-1.89*</td>
</tr>
<tr>
<td>Credit</td>
<td>δ₄</td>
<td>0.49</td>
<td>0.29</td>
<td>1.66*</td>
</tr>
<tr>
<td>Extension</td>
<td>δ₅</td>
<td>3.21</td>
<td>1.74</td>
<td>1.86*</td>
</tr>
</tbody>
</table>

* , **, and *** are statistically significant at 10%, 5%, and 1%, respectively; ns means not significant. Source: Frontier output.

There is a vast literature on the relationship of farm size and efficiency. Although the estimated coefficient on farm size was negative (positive relationship with efficiency), it has no significant effect on the inefficiency. This implies that inefficiency does not depend on farm size. This result is in line with the finding of Kalirajan (1981), Bravo-Ureta and Pinheiro (1997), Idiong (2007).

The effect of formal education, usually measured in years of schooling, on technical efficiency of farmers is one of the socio-economic factors that has been given great attention in the frontier production function literature. The coefficient of education is estimated to have a statistically significant negative effect upon the inefficiency effects at 10% level. That is, education supports the notion that farmers with 6 or more years of formal schooling tend to present higher level of rice yield. This might be the result of farmers’ better skills, access and understanding of information, and better farm planning. This is because farmers with higher level of education are more likely to participate in training and to be receptive to adopt new technologies. The finding on education is in conformity with other research such as Idiong (2007), Bravo-Ureta and Pinheiro (1997), Shehu et al. (2007), Battese et al. (1996).

Credit is an indispensable resource to produce rice in the study site since 98% of the surveyed farmers rely on credit to grow rice. The coefficient of credit is estimated to have a statistically significant positive relationship with inefficiency at 10% level. The sign of this coefficient is unexpected. This indicates that to borrow money from rice sector moneylenders or input suppliers is not allowing rice farmers to enhance productivity. This finding is in agreement with the work of Battese and Broca (1997) in Pakistan for a sample of wheat farmers. Nonetheless, our results contradict the work of Idiong (2007). A possible explanation for such finding might be a wrong choice and untimely acquisition of production inputs. That is, the selection of production inputs is done based on money lenders’ suggestions rather than on a technical recommendation. Further, money lenders unilaterally fix the amount of money to be lend to farmers on area basis, causing farmers to face somehow cash constrains and therefore limiting the adoption of new technologies and acquisition of technical information. The coefficient of consultation with extension staffs is also estimated to have a statistically significant positive effect upon inefficiency effects at 10% level. This indicates that farmers contact with extension staffs is significantly not contributing to improve technical efficiency in rice production in the study area. This might be due to an ineffective role of the extension service. That is, extension staffs are not providing information that help farmers to overcome their current problems. Another possible explanation is that some of the problems faced by farmers are out of the scope of extension staffs possibilities.
The frequency distribution of efficiency of rice farmers in Monte Cristi province is presented in Table 3. The maximum and minimum values of technical efficiency are 98 and 36, suggesting that the 'best' practice farmer operates at 98% while the 'least' practice farmers operate at 36% efficiency level, respectively. Table shows that the average technical efficiency is recorded to be 85.0% in the study area, indicating that farmers could improve technical efficiency by some 15%, on average with the current set of inputs and the given technology at that time. The table further reveals that the average rice farmer would realize about 13% in cost saving, if the farmer was to attain the level of the most efficient farmer in the sampled area. It also can be seen from the table 3 that about 79% of the farmers exhibited a technical efficiency greater than 80%, indicating that on the relative term more than one-third of the farms were fairly efficient.

### Table 3 Frequency distribution of efficiency of rice farmers in Monte Cristi province

<table>
<thead>
<tr>
<th>Efficiency class</th>
<th>No. of farmers</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.31-0.40</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>0.41-0.50</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>0.51-0.60</td>
<td>2</td>
<td>2%</td>
</tr>
<tr>
<td>0.61-0.70</td>
<td>3</td>
<td>3%</td>
</tr>
<tr>
<td>0.71-0.80</td>
<td>13</td>
<td>14%</td>
</tr>
<tr>
<td>0.81-0.90</td>
<td>26</td>
<td>28%</td>
</tr>
<tr>
<td>0.91-1.00</td>
<td>47</td>
<td>51%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>93</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Mean 0.85
Minimum 0.36
Maximum 0.98

Source: Frontier output.

IV Concluding Remarks and Policy Implications

This paper has presented measures of technical efficiency and identified factors related with efficiency of a sample of 93 rice farmers in Monte Cristi province, DR. The estimated coefficients on pesticides, labor, and hired machinery service expenses had positive and significant effect on rice yield. Therefore, increasing these inputs would increase rice yield. The study indicates that rice farmers are 85% technically efficient, suggesting that there is 15% potential to increase TE with the given set of inputs and the available technology, on average. Further, about 51% of the farmers operated their farm greater than 90% efficiency level. It was found out that the main differences in technical efficiency among farmers may come from yield, and this is the result of different resource use practices across farms. Analyzing the farmer/farms factors related with efficiency, the study reveals that the coefficients on source of land, farm size, and education have a positive effect on efficiency. Nonetheless, only the coefficient on education was statistically significant at 10% level. While source of credit (rice sector moneylenders) and contact with extension staff increase technical inefficiency. Therefore, from a policy-maker point of view, education, source of credit and contact with extension staff are key factors to increase TE of rice farmers in the study site. Thus, the provision of literacy campaigns, training, and field day demonstration on best practice farms as well as to encourage farmers to engage in adult/continuing education programs may help inefficient farmers to become better off in the short run. Asadullah and Rahman (2009) concluded that both household head’s educational level and the presence of an educated adult member (primary and secondary education) in the household raise farm productivity, improve efficiency, and boost potential output. Therefore, increasing public investment in education, especially devoted to foster education in rural areas, might contribute to improve the level of education and hence overall agricultural sector performance for the long run.

Since to take credit from rice sector moneylenders increase technical inefficiency, policies intended to improve farmers access to institutional credit are required. Likewise, the provision of resources at low interests by the Dominican Agricultural Bank along with other non-governmental agencies is at the cornerstone of meeting farmers’ resource constraints. Considering that access to credit and consultation with extension staffs have a statistically significant negative relationship with efficiency, extension services are not being properly disseminated in the study area. Therefore, there is need of a structural reform of the extension service in the DR.
That reform may include the fostering of extension service technical staffs' capacities to cope farmers' demands; the determination of crop management practices for each area and the efficient dissemination of them. Since IDIAF has been developing high-yielding rice varieties among other technologies and techniques, there is a strong need to strengthen the link between extension service and research institutions in order to effectively transfer to farmers new developments. Likewise, the reorientation of educational programs for extension technical staffs at universities is at the cornerstone of a structural reform of the service since most of the universities' curriculum is focused on production aspects rather than management. These policy recommendations may aim to strengthen extension service, bridge the gap between efficient and inefficient farmers, and therefore improve efficiency levels of rice farmers in the study area. Further research, nonetheless, is required to estimate allocative and economic efficiency, analyze the effect of 15% TE potential increase on rice sector's competitiveness along with the implementation strategy of the suggested policies.

References