Factors Influencing Technical Efficiency of Agricultural Cooperatives in Dong Thap Province of Vietnam: An Application of Three-Stage DEA

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Abstract: This study estimates the technical efficiency of 45 agricultural cooperatives in 2015 from Dong Thap province of Vietnam using three-stage DEA model. The results showed that efficiency scores of cooperatives in the third stage slightly increase compared to those in the first stage. In addition, the study also indicates that technical training and infrastructure index are significant variables that have impacts on technical efficiency of cooperatives. Specifically, while technical training is found to be a favorable factor that has negative effects on slacks of inputs leading to improvement in cooperative efficiency, the opposite is true for infrastructure index. The study suggests service quality of cooperatives need to be improved to encourage the use by member farmers, meanwhile attract non-member farmers joining the cooperative such that the double missions of cooperatives can be achieved, that is, to pave the way of food security and rural development.

Key words: Agricultural cooperatives • Three-stage DEA • Productive efficiency • Vietnam

INTRODUCTION

Data envelopment analysis (DEA) is one of the common methods applied in agricultural economics to estimate efficiency of farming systems, farms or households. In literature, one stage DEA and two stage DEA are being broadly applied. In which the later does take into account the effects of environmental factors on efficiency in the second stage where these factors are regressed with efficiency indices obtained from the first stage DEA.

As noted by [1], in the traditional DEA approach, all inputs were assumed to be discretionary. Therefore, in the one stage DEA models, non-discretionary inputs do not be taken into consideration. In reality, production was usually affected by external factors such as exchange rate, economic situation and even weather conditions. In case of the two stage DEA, although non-discretionary are included in the regression analysis in the second stage, adjustments obtained from this approach are mainly based on the error term, as a result inefficiency tends to be overstated. Therefore, three-stage DEA model was introduced by [1]. The model can decompose environmental effects and inefficiency in the second stage and efficiency measures in the third stage are still maintain appropriate assets of the DEA procedures [2].

Although the three-stage DEA model is widely used to estimate efficiency of firms in many sectors such as schools, banks, they are not explored much on agriculture fields. It has been applied by [3] to estimate production efficiency of fishery in Zhoushan new District of China and by [4] for measuring efficiency of rice production in Thailand.

The aim of this study is to apply the three-stage DEA model in estimating relative efficiency of agricultural cooperatives and identify both favorable and unfavorable factors associated to their efficiency. The crucial roles of agricultural cooperatives have been determined for a long time in assisting small producers and individual farmers improving their efficiency. Such assistances are of more
importance in rural areas of developing countries. For instance, [5] studied on agricultural cooperatives in Ethiopia and found that they provided support services for members effectively such that it contributed to improvement of members’ technical efficiency. This is because when involvement in cooperatives, smallholder farmers can productively access inputs as well as useful linkages to extension. However, attracting farmers joining cooperatives is not an easy task and undoubtedly cooperatives of low efficiency deter farmers’ participation. Therefore, it is necessary to routinely measure cooperative’s efficiency and identify the determinants of efficiency to gauge its performances such that it can secure the cooperative service quality; by serving well to members can arouse more involvement among them and further to promote the membership of cooperative to non-member farmers. Improvement of agricultural cooperatives’ efficiency is not only significant, according to FAO, IFAD and WFP[6], to pay the way of food security but also of rural development.

Several studies have been conducted to examine cooperatives’ performance in the Mekong delta of Vietnam [7-10]. These studies mainly focused on descriptive analysis and SWOT (Strengths, Weaknesses Opportunities and Threats) analysis. In addition, there are also studies focused on comparing efficiency between member and non-member of cooperatives [11]. To the best of authors’ knowledge, this is the first study applying three-stage DEA model to estimate technical efficiency of agricultural cooperatives and identify factors that may attribute their efficiency. The results could help to understand the current status of cooperatives’ efficiency and recommendations therefore could be drawn for further improvement of agricultural cooperatives.

**MATERIALS AND METHODS**

**Empirical Models:** This study employed the three-stage DEA which was developed by [12, 13] in measuring technical efficiency for agricultural cooperatives and identifying environmental factors associated with inefficiency effects. The advantage of this approach is that it takes environmental variables into consideration while the one-stage model could not perform well.

In the first stage, only inputs and outputs variables were included in the standard DEA model to obtain initial efficiency scores. The input-oriented BCC model which proposed by [14] was adopted. The formula of the model is specified as follow:

\[ TE_{VRS} = \min_{\theta, \lambda} \theta \]

Subject to

\[ Y\lambda - Y_0 \geq 0, \quad \theta X\lambda - X\lambda \geq 0, \quad \lambda \geq 0 \]

where \( Y \) and \( X \) are output and input vectors, respectively; \( \theta \) represents a scalar; and \( \lambda \) is an \( n \times 1 \) vector of constants. The \( \theta \) value ranges from 0 to 1. Technically efficient farm has an efficiency score of one. In contrast, efficiency score of inefficient farm is lower than one.

In the second stage, the input slacks which were obtained in the first stage DEA together with efficiency scores were used in the regression models to examine the impacts of external factors.[15] stated that the value of the input slacks represents the difference between the actual input and the optimal input. There are three factors affecting these slacks, i.e., the management inefficiency, the statistical noise and the environmental variables. In this stage, many regression approaches have been applied such as Tobit [12], stochastic frontier analysis [13, 15, 16]. Moreover, [2] compared three regression models namely ordinary least squares (OLS), non-parametric and fractional logit; and found that the results were quite similar. This study employed OLS model in the second stage and it is specified as equation (2).

\[ S_{ik} = f_i(Z_{ik}, \beta) + e_{ik} \]

where \( S_a \) is the input slacks, \( Z_a \) is the vector of environmental variables that may affect the input, \( \beta \) represents unknown parameters and \( e_a \) is error term.

Then the estimated coefficients obtained from the regression model are used to calculate the predicted value of total input slack for every input.

\[ S_{ik}^{\text{predicted}} = f_i(Z_{ik}, \hat{\beta}) \]

These values are then used in order to adjust data of each original input.

\[ X_{ik}^* = X_{ik} + \left[ \max_{a} \left( S_{ik} - S_{ik}^{\text{predicted}} \right) \right] \]

where \( X_{ik}^* \) and \( X_{ik} \) are adjusted and original values of the \( i \)th input, \( \max_{a} \left( S_{ik} - S_{ik}^{\text{predicted}} \right) \) is the different value of maximum predicted slack of the \( i \)th input and its predicted slack [12].
In the third stage, the traditional DEA model is re-run using adjusted inputs and original outputs to estimate the adjusted efficiency scores.

Data and Variables: The input and output variables related to business activities of 45 agricultural cooperatives in 2015 were used for estimating technical efficiency. Data were annually gathered by the Division of Rural Development, Department of Agriculture and Rural Development of Dong Thap province in Vietnam. Furthermore, information associated with cooperatives’ characteristics were also collected by using structured questionnaires in December, 2015.

In this study, DEA model is performed with the three inputs and two outputs. The choices of variables are based on references from previous studies related to cooperatives comprising [17-19]. Because the subject of this study is agricultural cooperative which is closely related to agricultural activities, therefore, revenue and profit; number of members, number of hectares served and total capital were chosen as output and input variables, respectively. Members are included in the model due to their important contributions in many activities of cooperatives. Total area served by cooperatives is considered as one important index because it is associated with the social-economic role of cooperatives in serving their members farmers in the nearby communities.

In terms of explanatory variables used in the second stage of OLS regression, socio-economics and characteristics related to cooperatives were assumed to have influences on their efficiency. These variables include the age and education level of cooperative’s leader (years), technical training for members (dummy variable, takes 1 if member received trainings in previous year; 0 otherwise), credit access (dummy variable, takes 1 if cooperative accessed to credit in previous year; 0 otherwise) and infrastructure index (represents the quality of road network supporting for cooperatives’ transportation, expressed in number from 1 to 5, the higher value indicating the better quality of infrastructure). The descriptive statistics of inputs, outputs and socio-economics variables are illustrated in Table 1.

RESULTS AND DISCUSSION

The Results of OLS Regression in the Second Stage: Slacks of three inputs were obtained from analyzing efficiency of 45 agricultural cooperatives in the first stage using BBC DEA model. These slacks were then regressed with cooperative’s characteristics using OLS model. The results are demonstrated in Table 2. All of five factors were included in Model 1 and three of them, i.e., age, education of cooperative’s leader and credit access, did not show any impacts on all input slacks. Specifically, slack of the input of number of member seem to be not affected by all these characteristics of cooperative and hence the adjusted value of this input remains unchanged. Therefore, only two variables, training and infrastructure index, were applied in Model 2. From Table 2, it shows that the two variables, training and infrastructure, were highly significant on both area and capital slacks, indicating that the impacts are clearly presented and cannot be overlooked. Therefore, Model 2 was chosen to adjust slacks of input area and capital.

The signs of the estimated coefficients are indicators to identify linkage of explanatory variables to input slacks. According to [15], in the regression analysis between environmental variables and input slack variable, a positive sign of coefficient indicates that an increase in environmental variable, the corresponding input slack will also increase which will result in the input waste and as a
Table 2: The OLS results for factors influencing input slacks of agricultural cooperatives.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slack of members</td>
<td>Slack of total area</td>
</tr>
<tr>
<td>Constant</td>
<td>163.762</td>
<td>-11.244</td>
</tr>
<tr>
<td></td>
<td>(130.786)</td>
<td>(11.751)</td>
</tr>
<tr>
<td>Age</td>
<td>-2.589</td>
<td>0.160</td>
</tr>
<tr>
<td></td>
<td>(1.707)</td>
<td>(0.153)</td>
</tr>
<tr>
<td>Education</td>
<td>0.203</td>
<td>0.866</td>
</tr>
<tr>
<td></td>
<td>(5.758)</td>
<td>(0.517)</td>
</tr>
<tr>
<td>Training</td>
<td>7.479</td>
<td>-8.900**</td>
</tr>
<tr>
<td></td>
<td>(33.722)</td>
<td>(3.030)</td>
</tr>
<tr>
<td>Credit access</td>
<td>-14.761</td>
<td>-1.758</td>
</tr>
<tr>
<td></td>
<td>(23.875)</td>
<td>(2.145)</td>
</tr>
<tr>
<td></td>
<td>(8.326)</td>
<td>(0.748)</td>
</tr>
<tr>
<td>R-square</td>
<td>0.086</td>
<td>0.293</td>
</tr>
<tr>
<td>Sig.</td>
<td>0.604</td>
<td>0.016</td>
</tr>
</tbody>
</table>

Note: * and ** represent significant at 5% and 1%, respectively; standard errors are in parenthesis

As presented in Table 2, training variable showed negative influences on both slacks of total area and capital. This means that when cooperative members received technical trainings, cooperatives could decrease the waste of areas served and total capital used as well for their activities. This in turn helps cooperatives improve their revenue and profit as well. This may be because farmers have more opportunities to access important information and knowledge from agricultural extensions when participating in training held by cooperatives and hence their efficiency could be enhanced which further lead to improve efficiency of cooperatives. As stated by [5], being member of cooperatives, small farmers can have useful linkages to agricultural extensions and then get better access to advanced farming practices that contribute to the increase in productive efficiency.

Regarding infrastructure index, it showed a positive influence only on slack of area, implying that better quality of transportation systems tends to reduce the outputs of cooperatives. This is not as expected because usually it is believed that good transportation systems brings certain advantages for cooperatives such as expansion of service activities and reduction of transportation costs for inputs and outputs and hence outputs would be increased. This result may be because when transportation systems have improved, cooperatives face with competition from private sectors for providing agricultural services to farmers. Farmers have alternative option for farming services and therefore the total area served by cooperatives may decrease as a result.

The DEA Results before and After Adjusting Inputs Due To Influence of External Factors: Cooperatives are categorized by the officials of the Rural Development Division, Department of Agriculture and Rural Development based on the classification systems issued by government. There are four grades of cooperative performance in the system, i.e., weak, fair, good and excellent. However, there were only three types; fair, good and excellent cooperatives; adopted in this study due to the availability of data.

Technical efficiency scores of cooperatives in the first and the third stages were analyzed by using DEAP 2.1 software [20]. The results are presented in Table 3. In the first stage, the mean technical efficiency scores under constant returns to scale and variable returns to scale (TE CRS and TE VRS) and scale efficiency (SE) of the sample cooperatives were 0.591, 0.778 and 0.779, respectively. Under variable returns to scale, cooperatives with excellent performance obtained the highest efficiency score (0.854), followed by fair cooperatives (0.841). Although good cooperatives achieved quite low efficiency value (0.695), their mean scale efficiency was the highest (0.796). Compared with the efficiency indexes in the first stage, there was a noticeable change in the third stage. There were slightly increases of TE CRS, TE VRS and SE (0.598, 0.784 and 0.781) indicating there were impacts of factors related to cooperative characteristics
on efficiencies. In addition, it is important to note that efficiency estimates and their changes from stage 1 to stage 3 in these three groups of cooperative performances are also different. While efficiency indexes of good and excellent cooperatives have improved, fair cooperatives have experienced a decrease in all efficiencies. This shows that cooperatives with fair performances are more susceptible than others.

In general, the estimated technical efficiency scores of these cooperatives were fairly low. On average, TE VRS of cooperatives in both stages were all less than 0.600, suggesting that productive efficiency could be increased almost 40% if inputs were used more efficiently.

Distribution of efficiency scores is illustrated in Table 4. There was a change in distribution of efficiency scores between the first and the third stage, but it was quite small. It is important to note that majority of the cooperatives in the sample (over 40%) obtained very low TE CRS, i.e., less than 0.500; while only about 13% of them were fully efficient. In other words, there were almost 87% of cooperatives in this study are considered to be inefficient with the TE CRS scores less than 0.900, indicating these cooperatives need more attentions and support to improve their efficiency.

**CONCLUSIONS**

Some important implications could be drawn from the findings by using three-stage DEA model in efficiency measurement of agricultural cooperatives in the present study. The results showed that taking technical training by members is found to be a favorable factor associated with two input slacks of total area served by cooperatives and capital, while the quality of infrastructure system is an unfavorable factor related only to slack of total area served by cooperatives. The efficiency scores of cooperatives have changed in the third stage. While efficiency scores of the good and excellent cooperatives have enhanced, those of the fair cooperatives have experienced slightly decreases. Therefore, this study suggests that agricultural cooperatives should pay more attentions on their current strength in assisting members to access better farming practices more easily. Finally, service quality of cooperatives needs to be improved to encourage more use of service by member farmers and meanwhile to attract more membership applied from non-member farmers as well.

**REFERENCES**