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Technical, Allocative and Economic Efficiency of Pineapple Production in West Java Province, Indonesia: A DEA Approach

Riatania Lubis[1], Arief Daryanto[1], Mangara Tambunan[1], Handewi Purwati[2]
[1](Faculty of Economics and Management, Bogor Agricultural University, Indonesia)
[2](Indonesian Center for Agricultural Socio Economic and Policy Studies, Ministry of Agriculture, Indonesia)

Abstract: *Low productivity in horticulture is mainly due to the inability of the farmers to exploit the available technologies fully, resulting in lower efficiencies of production. Data Envelopment Analysis (DEA) is used to estimate technical, allocative and economic efficiency also Tobit regression is used to determine factors of technical and economic inefficiency in the pineapple cultivation on 142 farmers in West Java Province, Indonesia. The study has indicated that most of the pineapple farms have shown technical, allocative and economic inefficiency problems. Data Envelopment Analysis (DEA) results showed that farmers were inefficient in the pineapple production with mean technical, allocative and economic efficiency level of 70.1%, 34.1% and 24.1%, respectively. A Tobit regression model results on the determinants of fifteen socio-economic, demography and institutional variables revealed that land productivity had positive and significant contribution on technical and economic efficiency. Market distance and capital productivity had positive and significantly influenced the technical efficiency and labor productivity also land ownership had positive and significant contribution to the economic efficiency. Counseling and off-farm income contributed negatively to the technical efficiency and farmer experience also contributed negatively to the economic efficiency. These finding suggests that pineapple production in the research location would be significantly improved by cultivating on farmer's own land and getting better counseling from about the pineapple's good agricultural practices.*

Keywords: *Data Envelopment Analysis (DEA), economic efficiency, technical efficiency, Tobit regression, Variable Return to Scale (VRS)*

I. Introduction

One of the main reasons for low productivity in horticulture all over the world, including Indonesia is the inability of farmer to fully exploit the available technologies, resulting in lower efficiencies of production [1]. Pineapple is one of the leading horticulture crops grown in Indonesia which contributing 7 percent to the total Indonesian fruits production (1.4 million tons) and providing 77 percent to the export value of processed fruit (148 million US$) in 2012 [2]. Fresh pineapple demand has been increasing in the last few years [3], it contributes to the improvement of pineapple production. Most of pineapple cultivation in Indonesia conducted by small scale farmers which the main challenges faced by those farmers are market restriction, low price, less commitment and trust between farmer - buyer, lack of capital and credit access, plant disease and land ownership problem [4].

West Java Province is one of the production centers for pineapple in Indonesia that contributes about 10 percent of the Indonesia's pineapple commodity products in 2012; other provinces are Lampung (33%), North Sumatra (15%) and East Java (11%). About 4 years ago, pineapple production from West Java Province contributed almost 30 percent to the total pineapple production in Indonesia. West Java has been decreasing in pineapple production allegedly due to the climate change's effect and low level of efficiency. Bakhsh et al. (2006) mentioned three possibilities to increase production which are adding land area, developing and adopting new technology and using available sources efficiently [5]. In order to achieve the vision of a high-income country, farmers are expected to operate under a much more competitive condition and increase their efficiencies to survive [6]. Efficiency improvement can also decrease the production cost that can improve the farmer's welfare [7]. Determining the existing level of efficiency will be useful to improve these relationships that can help farmers allocate their resources more wisely and also to assist the government in designing and searching for new policy tools to reach sector-specific goals.

Theoretically, there are three sources of productivity improvements, technological change/TC, increasing of technical efficiency/TE and economic of scale/ES [8]. Some of study results showed that production inefficiency level influenced by socio-economic and demography variables, such as farmer age, number of family member, education level, association participation, knowledge on cultivation technology, experience and off farm income [1], [4], [9].

II. Methodology

1.1 Data Envelopment Analysis (DEA)

Farrell (1957) proposed that efficiency of any given firm is composed of its technical and allocative components. Technical efficiency/TE is associated with the ability of a firm to produce on the Iso-quant frontier while allocative efficiency/AE refers to the ability of a firm to produce at a given level of output using the cost-minimizing input ratios. The combination of technical and allocative efficiency becomes economic efficiency which defined as the capacity of a firm to produce a pre-determined quantity of output at a minimum cost for a given level of technology [8].

Various methods to estimate efficiency have been developed and classified as parametric and non-parametric approaches. Data Envelopment Analysis (DEA) was first introduced by Charnes et al. (1978) and it has served as the corner stone for all subsequent developments in the non-parametric approach [10]. DEA has several advantages: it can handle multiple outputs and inputs, it does not require a prior specific functional form for the production frontier, it does not require the distributional assumptions of the inefficiency term, and it also possible to identify the best practice for every farm [8]. Regarding its potential disadvantages, DEA is sensitive to extreme observations and a hypothesis testing is not possible.

Suppose there are n homogenous Decision-Making Units (DMUs), in order to produce r number of outputs (r=1,2,3,…k) s number of inputs are utilized (s=1,2,3,… m,) by each DMU i (i=1,2,3,…n). Assume also that the input and output vectors of i^{th} DMU are represented by xi and yi, respectively and data for all DMUs be denoted by the input matrix (X)m×n and output matrix (Y)k×n. Accounting for financial limitations or imperfect competitive market effects, the DEA model for variable returns to scale (VRS) which was developed by Banker, Charnes and Cooper (BCC) (Banker et al. 1984) is used [11]. The input minimization process to measure technical efficiency for each DMU can be expressed as equation (1):

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\ \phi, \\ &\text{st}\quad -y_i + Y\lambda \geq 0, \\ &\qquad \phi x_i - X\lambda \geq 0, \\ &\qquad N1'\lambda = 1 \\ &\qquad \lambda \geq 0 \end{aligned} \tag{1}$$

where, in the restriction N1'λ=1, N1' is convexity constraint which is an N×1 vector of ones and λ is an N×1 vector of weights (constants) which defines the linear combination of the peers of the i^{th} DMU. $1\leq \phi \leq \infty$ and ϕ - 1 is the proportional increase in outputs that could be achieved by the i^{th} DMU with the input quantities held constant and $1/\phi$ defines a technical efficiency score which varies between zero and one. If ϕ =1 then the farm is said to be technically efficient and if ϕ<1 the farm lies below the frontier and is technically inefficient.

Similarly, to estimate economic efficiency (EE), a cost minimizing DEA is specified as equation (2) :

$$\begin{aligned} &\text{Min}_{\lambda,Xi^*}\ W_i'\,Xi^* \\ &\text{st}\quad -y_i + Y\lambda \geq 0, \\ &\qquad Xi^* - X\lambda \geq 0, \\ &\qquad N1'\lambda = 1 \\ &\qquad \lambda \geq 0, \end{aligned} \tag{2}$$

Where, W_i' is a transpose vector of input prices for the i^{th} DMU and Xi * is the cost-minimizing vector of input quantities for the i^{th} farm given the input prices Wi and total output level yi. Economic efficiency is measured as the ratio of potential minimum cost of production (Wi $'Xi^*$) to the actual cost of production (Wi'Xi*). Allocative efficiency can be estimated as the ratio of economic to technical efficiencies as AE=EE/TE. In order to generate the technical, economic and allocative efficiency scores DEAP Version 2.1 computer program described in Coelli (1996) was used.

This study using six input variables: pineapple land area (ha), seed (clump), hired labor (man-days), ethrel (liter), dung (kg), and chemical fertilizer (kg).

2.2 Tobit Regression Analysis

The present study uses a censored regression to analyze the role of socio-economic, demography and institutional attributes in explaining technical and economic efficiency in pineapple production. Tobit regression was introduced by Tobin (1958) involving a censored regression model of the economy and first analyzed in the econometric literature [12]. As the efficiency index derived from data envelopment analysis is bound between 0 and 1 value, thus it is suitable for use as a simulation analysis to identify the determinant of technical efficiency among farmers. Efficiency index derived from the Equation 1 and 2 can be used as a measure of the performance of farmers. Briefly, Tobit's regression can be written as follows:

$$y^*_t = x'_t \beta_0 + \epsilon_t,\ t = 1, 2, 3,...,n \quad (4)$$

$$y_t = y^*_t \ \text{ if } y^*_t > c \text{ ; and } y_t = c \text{ , otherwise} \quad (5)$$

where, y_t is a DEA efficiency index used as a dependent variable, $\epsilon_t|x_t$ is $N(0,\sigma_0^2)$ and $\{y_t,x_t\}(t = 1,2,...,n)$ is vector of independent variables related to farm-specific attributes, value of c is known. y_t^* is a latent variable. β is an unknown parameter vector associated with the farm-specific attributes and ε is an independently distributed error term that is assumed to be normally distributed with zero mean and constant variance, σ^2. A Tobit regression model applying the maximum likelihood approach is used to estimate the model in Equation 4 such that Equation 6:

$$L = \prod_{yt=0}(1 - Ft)\prod_{yt>0}\frac{1}{(2\prod\sigma^2)^{1/2}}e[1/2\sigma^2](yt - \beta x)^2$$

$$\text{where, } F_t = \int_{-\infty}^{\beta^t xt/\sigma}\frac{1}{(2\prod^{1/2})}e^{-\frac{t^2}{2}}\,\partial i\ . \quad (6)$$

The Equation 5 refers to the efficiency score of farmers 100% (y = c) and the second term represents inefficient farmers (y > c). Ft is normally scattered in the $\beta^t x_t / \sigma$. Farm level technical and economic efficiency scores are used in the regression model to show the relationship between the measurement of the efficiency and characteristics of farmers. Based on the literature, several variables have been identified to explain the technical and economic efficiency levels among farmers in the study area. The variables are age (x1), family member (x2), market distance (x3), cropping pattern (x4), land productivity (x5), labor productivity (x6), capital productivity (x7), experience (x8), formal education (x9), association participation (x10), credit access (x11), counseling (x12), training (x13), off-farm income (x14) and land ownership (x15).

III. Results And Discussion

1.2 The Study Area and Data

This study used primary data of 142 respondents from the total of 282 pineapple farmers located in Subang District, West Java Province by using sampling fraction and structured questionnaires. Subang District is the biggest pineapple production center in West Java Province with share of production was 98.4 percent in 2012. Most of the pineapples marketed freshly to the traditional market and hypermarket in West Java and Jakarta Provinces.

Table1. Output and Input Variables of the Study

Variables	Mean	Standard Deviation	Minimum	Maximum
Pineapple Output (kg)	5,602.5	10,582.1	150	100,000
Land Area (ha)	0.68	2.2	0.01	25
Seed (clump)	24,372.9	71,126.2	700	800,000
Hired labor (man-days)	219.4	577.6	12	6,500
Ethrel (liter)	1.6	4.7	0.25	45
Dung (kg)	9,603.9	30,513.8	100	35,000
Chemical Fertilizer (kg)	347.3	745.1	10	6,200

Output and input variables used in the DEA study showed in Table 1. Pineapple output average produced by the farmers was 5.6 ton per year with standard deviation is 10,582.1 indicates output variability among the farmers. Land area average used by farmer to cultivate pineapple was 0.68 hectare with average seed usage was 24,372.9 clumps per hectare. Average of hired labors is 219.4 man-days indicating farmer still labor intensive and most of the cultivation activity done only by the farmer. Other production inputs such as ethrel, dung and chemical fertilizer average using by farmer was 1.6 liter; 9,603.9 kg and 347.3 kg per year, respectively.

1.3 The DEA Results

The estimated and distribution of technical, allocative and economic efficiency levels using the VRS-DEA model are presented using Table 2. The results showed that the mean levels of technical, allocative and economic efficiency scores ware 0.701, 0.341 and 0.241, respectively. The mean score of technical efficiency implies that a pineapple farmer could decrease current input by 29.9% to produce the same amount of output. The result for mean allocative efficiency also suggests that cost of production could be reduced by 65.9% had farmers used the right inputs and outputs mix relative to input costs and output prices. On the other hand, the mean level of economic efficiency indicates that farmers could reduce current average cost of production by 75.9% to achieve the potential minimum cost of production relative to the efficient farmers given the current output level. These efficiency results suggest that there is considerable potential for decreasing input and reducing cost of production. Furthermore, it is revealed that 42.25%, 3.52% and 3.52% of farmers are fully technically, allocatively and economically efficient.

Table 2. Distribution of Technical (TE), Allocative (AE) and Economic Efficiency (EE)

Efficiency Categories	TE		AE		EE	
	Freq.	Percentage	Freq.	Percentage	Freq.	Percentage
E<0.1	2	1.41	10	7.04	37	26.06
0.1<E≤0.2	2	1.41	30	21.13	41	28.87
0.2<E≤0.3	13	9.15	37	26.06	30	21.13
0.3<E≤0.4	13	9.15	20	14.08	10	7.04
0.4<E≤0.5	24	16.90	15	10.56	10	7.04
0.5<E≤0.6	9	6.34	9	6.34	4	2.82
0.6<E≤0.7	5	3.52	13	9.15	2	1.41
0.7<E≤0.8	7	4.93	2	1.41	2	1.41
0.8<E≤0.9	6	4.23	1	0.70	1	0.70
0.9<E≤1.0	61	42.96	5	3.52	5	3.52
Full Efficient Farmers	60	42.25	5	3.52	5	3.52
Inefficient Farmers	82	57.75	137	96.48	137	96.48
Mean Scores	0.701		0.341		0.241	

Note : E = Efficiency

1.4 The Tobit Results

In order to identify key determinants of resource use inefficiency, technical and economic inefficiency scores were separately regressed on selected demographic, socio economic and institutional variables. Table 3 presents descriptive statistics of the variables used in the analysis of resource use inefficiency.

Results reveal that age of farmer is on average 55 years while the mean level of family member is 4.5 persons (Table 3). The study also shows that average market distance is 1.57 km from the farm, with average farming experience is 18.39 years, and the farmers followed the formal education for average 6.95 years, and have average off-farm income Rp 8,611,360 per year. Land productivity of pineapple farming is average 14,244.04 kg per ha with labor productivity is 15.62 % and capital productivity is 8.6 %. Labor productivity measured in terms of total revenue from the pineapple divided by the total labor cost. Capital productivity estimated by dividing total yield with operating expenses. 3.94 percent of pineapple farmer had conducted the intercropped farming with other crops such as cassava, banana, chili and other trees. Only 65.49 percent of pineapple farmers have participated actively in pineapple association routinely. Pineapple farmers that take part on pineapple training conducted by the Subang District’s Agricultural Service Officer or other institutions is 29.58 percent. Besides using private capital, 7.04 percent of farmers had using the credit access from the local bank and 79.58 percent of farmers doing the cultivation on their own land.

Table 4 presents the determinants of technical and economic inefficiency in the production of pineapple. Market distance, land productivity and capital productivity results in significant reductions of technical inefficiencies among farm households. Counseling and off-farm income have positive effects on technical inefficiency.

Table 3. Descriptive Statistics of Variables for Tobit Regression

Variables (unit)	Mean	Min	Max
Age (year)	55	27	100
Family member (people)	4.5	1	9
Market distance (km)	1.57	1	15
Land productivity (kg/ha)	14,244.04	928	100,000
Labor productivity (%)	15.62	0.41	342.47
Capital Productivity (%)	8.6	0.41	255.92
Experience (year)	18.39	1	50
Formal education (year)	6.95	1	14
Off-farm income (Rp/year)	8,611,360	0	96,000,000

Dummy Variables	Category	Freq	Percent
Cropping pattern	Monoculture (0)	37	26.06
	Intercropped (1)	105	73.94
Association participation	No (0)	49	34.51
	Yes (1)	93	65.49
Credit access	No (0)	132	92.96
	Yes (1)	10	7.04
Counseling	No (0)	88	61.97
	Yes (1)	54	38.03
Training	Never (0)	100	70.42
	Ever (1)	42	29.58
Land ownership	Rent (0)	29	20.42
	One’s own (1)	113	79.58

Land productivity, labor productivity and land ownership negatively and significantly decrease the economic inefficiency or increase the economic efficiency while experience has positive and significant contributes to the increasing of economic inefficiency. Douglas (2008) also reveals the same result stated that experience has positive correlation with age where farmer become older then experience become longer and the creativity become lower [13]. When the labor cost become lower than the labor productivity become higher and will increase the economic efficiency. Farmer whose cultivated on his own land will economically efficient because the tax that farmer paying is lower than the land rent the farmer have to pay. The increasing of production cost will imply to the decreasing of economic efficiency of pineapple farmers.

Land productivity contributes positively and significantly to increase the technical and economic efficiency. This result is consistent with Murthy et al. (2009). With higher output per hectare, the income of the farmer also increased and the implication is they can buy enough input production to improve the technical and economic efficiency.

Market distance contributes negatively and significantly to technical inefficiency or it can increase technical efficiency. Narala and Zala (2010) also found that distance to the market can increase the technical efficiency [14]. Counseling and off-farm income results positive and significant to the increasing of technical inefficiency. Farmer that only focused on the farming will be technically efficient compare than farmer that has off-farm activities [9], [15].

The importance of pineapple commodities to the farmer's welfare and as raw material to the processed fruit industries, the technical, allocative and economic efficiency are necessary to be improved. By fulfilling the standard requirement requested by the traditional and industry markets also performing the good agricultural practices hopefully could improve the pineapple production efficiency in Subang District, West Java Province, Indonesia. Moreover, policies and strategies should also support the monoculture application which can reduce the negative effect of production efficiency. Furthermore, farmers' associations should also be re-structured in personnel and technology in order to ensure member households are benefited from their membership and improve their resource use efficiency.

Table 4. Results of Tobit Regression Analysis

Independent variables	Technical Inefficiency			Economic Inefficiency		
	β	Std E	t	β	Std E	t
Age	0.00108	0.00264	0.41	-0.00017773	0.00161	-0.11
Family member	-0.00276	0.02093	-0.13	-0.01505	0.01275	-1.18
Market distance	-0.03283***	0.01753	-1.87	-0.00400	0.01068	-0.37
Cropping pattern	0.00246	0.05718	0.04	-0.02271	0.03483	-0.65
Land productivity	-0.00000655*	0.00000176	-3.73	-0.00000631*	0.00000107	-5.89
Labor productivity	-0.00076983	0.00086190	-0.89	-0.00272*	0.00052500	-5.17
Capital productivity	-0.00227***	0.00123	-1.84	-0.00072231	0.00075088	-0.96
Experience	0.00009189	0.00243	0.04	0.00194****	0.00148	1.31
Formal education	-0.00842	0.01122	-0.75	0.00297	0.00683	0.43
Association	0.02496	0.06698	0.37	-0.04199	0.04080	-1.03
participation	-0.086999	0.10195	-0.85	-0.00075539	0.06210	-0.01
Credit access	0.09324****	0.06312	1.48	-0.02727	0.03844	-0.71
Counseling	0.02377	0.06097	0.39	0.03139	0.03714	0.85
Training	3.444464E-	1.96572E-9	1.75	6.62215E-10	1.197367E-	0.55
Off-farm income	9***	0.06431	-0.18	-0.07141***	9	-1.82
Land ownership	-0.01154				0.03917	

Note:***,**,***,***** = significance at 1%, 5%, 10%, and 20%

IV. Conclusion

The study established that pineapple farmers are inefficient in the production with mean technical, allocative and economic efficiency levels of 0.701, 0.341 and 0.241, respectively. A Tobit regression analysis results reveal that land productivity resulted in significant reductions of technical and economic inefficiencies. This positive effect of pineapple production efficiency could be through improving farmers' income, thereby ensuring that farmers are able to respond rapidly to demands for cash to buy inputs and other factors. It is also established that off-farm income and counseling associated with increase in technical inefficiencies. The study, however, reveals that market distance and capital productivity can improve technical efficiency. Labor productivity and land ownership also can improve the economic efficiency. Finally, it is found that farmer's experience can decrease the economic efficiency.

Finding of the study implies that there should be strategies to improve the farmer technique and fulfill the standard requirement so as to further improve the pineapple production efficiency in Subang District, West Java Province, Indonesia. Moreover, policies and strategies should also support the monoculture application which can reduce the negative effect of production efficiency. Furthermore, farmers' associations should also be re-structured in personnel and technology in order to ensure member households are benefited from their membership and improve their resource use efficiency.

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