

Determinants of technical efficiency of rice farming in dryland area of Central Lombok: An application stochastic frontier production function

Faktor penentu efisiensi teknis usahatani padi di lahan kering lombok tengah: suatu penerapan fungsi produksi stokastik frontir

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Abstrak

Pertanian memainkan peranan penting dalam pembangunan ekonomi di negara-negara berkembang termasuk Indonesia. Padi merupakan tanaman pangan utama untuk pertanian di Indonesia sebab beras merupakan makanan pokok bagi penduduk negara ini. Walaupun produksi padi secara nasional meningkat, produktifitas per satuan input menurun. Hal ini sangat erat kaitannya dengan efisiensi produksi. Studi ini menampilkan ukuran langsung dari efisiensi produksi menggunakan fungsi produksi stokastik frontier dan model pengaruh inefisiensi. Hasil studi menunjukkan bahwa terdapat efisiensi tinggi yang rata-rata 86,75 persen dalam penggunaan input usahatani. Faktor penentu tingkat efisiensi ini adalah umur, pendidikan, pengalaman berusahatani, ketersediaan kredit, lokasi usahatani dan jumlah tenaga kerja dalam keluarga.

Kata kunci: usahatani lahan kering, fungsi produksi stokastik, efisiensi teknis

Abstract

Agriculture plays important role in economic development for most developing countries including Indonesia. Rice is a main crop for agriculture in Indonesia because it is a staple food for the populations. Even though rice production nationally increases, the productivity per input uses basis decrease. This issue is related to production efficiency. This study provides a direct measure of production efficiency using a stochastic production frontier and inefficiency effects model. The result shows that there is high level efficiency in using farm input with on average 86.75 percent. The efficiency differences can be explained by age, education, experience, credit availability, farm location and number of family labour.

Key words: dryland farm, stochastic production function, technical efficiency

Introduction

Background and Problem Statement

Agriculture, especially "on-farm" agriculture, was considered as an important sector in economic development for most developing countries during the post-war period (van Kuelen *et al.* 1998). Rola-Rubzen and Hardaker (1999) also detailed some logical reasons why agriculture should be made an integral part of the development strategy in less developed countries (LDCs). In Indonesia, agriculture is a cornerstone of economic development. It showed that the Agricultural sector in this country played a major role as a source of economic growth, providing employment, foreign exchange earnings, and is the source of food supply and raw material for manufacturing industries (Sudaryanto *et al.*, 1992; Saragih, 2000), provide significant contribution to GDP in Indonesia and millions of low-skilled or non-skilled labour with employment for most of the population (Kasryno and Suryana, 1992; Anderson and Pangestu, 1995; Both, 1994; Tambunan, 1998).

One of the most important issues of this sector is the business related to paddy's production as rice is Indonesian main staple food. Paddy production was increase during 1980 to 2001 but the productivity was tending to decrease (Sumaryanto *et al.*, 2003). The authors reported that from 1980 to 1984 paddy production was 32.01 million tones and from 1995 to 2001 was 47.62 million tones but the productivity in these two period were 6.29 and 1.01 percent respectively. This situation threatens national food security for the future because rice demand is increase as the population increase.

Two reasons may be considered as main suspect for this situation. There has been an apparent decline in the average yields of popular rice varieties and the level of adoption of the new methods has stagnated. Renkow (1993) noted that increasing yield as a result of technological changes could lead to increasing producer's income, but only if costs and prices are kept under control. This issue is related to production efficiency.

In the case of Indonesia, where farmers face limitations in land area holding, capital access and knowledge, the problems related to farm level efficiency are becoming the most crucial issues in agricultural production activities. Efficiency analysis of agricultural production in Indonesia has focused primarily on irrigated farming production such as the work of Trewin *et al.* (1995) and Llewelyn and Williams (1996). The government and scientists have given less attention to dryland farming, even though its development was recognised as a main program in poverty alleviation.

This study will concentrate on the analysis of technical efficiency of rice farming which were cultivated in dryland areas of Lombok Island of Indonesia. The basic question which arises here is: *Are the farmers with their existing resource endowment, technology, current socio-economic environment and knowledge, able to allocate their existing resources in a technically efficient*

way? Furthermore, what are the significant determinants associated with the level of individual farmer's technical efficiency?

Development in Stochastic Frontier Production Functions Analyses

Following the pioneering but independent works by Aigner *et al.* (1977), Battese and Corra (1977) and Meeusen and van den Broeck (1977), serious consideration has been given to the possibility of estimating the frontier production function, in an effort to bridge the gap between theory and empirical work. In the last decade, various models have been proposed for the inefficiency effects in stochastic frontier production functions. Kumbhakar *et al.*, (1991) specified a stochastic frontier production function, in which the technical inefficiency effects were assumed to be a function of the values of other observable explanatory variables. In addition, their model considered allocative and scale efficiencies.

Battese and Coelli (1995) also proposed a stochastic frontier production function for panel data, in which the technical inefficiency effects were specified in terms of various explanatory variables, including time. Huang and Lui (1994) specified a non-neutral stochastic frontier production function in which the technical inefficiency effects were specified in terms of various firm-specific variables and interaction among these variables and the input variables in frontier. Reifschneider and Stevenson (1991) also proposed a stochastic frontier model in which the technical inefficiency effects were dependent on other variables.

A number of empirical studies have identified the sources of technical inefficiency, in addition to predicting technical efficiencies for the firms. One of the early empirical studies in stochastic frontier production function was an analysis of the sources of technical inefficiency in the Indonesian weaving industry by Pitt and Lee (1982). The study estimated a stochastic frontier production function by the method of maximum likelihood and the predicted technical efficiencies were then regressed upon some variables, including size, age and ownership structure of each firm, and were shown to have significant effect on the degree of technical inefficiency of the firms. Many subsequent empirical studies have investigated the sources of technical inefficiency in different industries using the same two-stage analytical method. However, studies by Kumbhakar *et al.* (1991), Reifschneider and Stevenson (1991), Huang and Lui (1994), Battese and Coelli (1993), Battese *et al.* (1996), have questioned the theoretical consistency of this two-stage analytical technique and have proposed the use of stochastic frontier specifications which incorporate models for the technical inefficiency effects and simultaneously estimate all the parameters involved.

Methodology

Study area

This study was carried out in dryland areas of the southern zone in Lombok Island with paddy crop cultivation. Data for this study were obtained from a face-to-face survey of 227 dryland farmers in Lombok, Indonesia. The survey was conducted between December 2005 and August 2006. This type of survey was considered suitable because it meant that it was possible to obtain high quality data by ensuring that respondents were able to clarify answers to questions using the local language or dialect and hence overcome problems associated with low levels of literacy among respondents and language sensitivity.

A total of 227 farmers were randomly selected from the Desa Kawo of Kecamatan Sengkol in the Southern zone. The village was purposively selected based on the criteria that farming in this village was 100 percent dryland and because the village had the largest dryland area in this zone. There were three types of farmers - maize, peanuts and cassava farmers. This study used stochastic frontier production function analysis. Single output production frontier models were constructed for each type of farm. This was then followed by regression analysis. Frontier functions were constructed to measure the level of farm-specific technical efficiency, while regression analysis was conducted to identify factors that influence farm-specific technical efficiency level. The variables used in the production function are described in the model specification below.

Model Specification

Farrel (1957) based on Debreu (1951) and Koopmans (1951) works introduced the definition and conceptual framework for technical efficiency and allocative efficiency under the frontier function approach that measuring the economic efficiencies of firm involved in the production of certain commodities based on the concept of Pareto of productive efficiency. The author notified the relative efficiency which compares efficiency of each producer with the best practicing producers. The basic structure of the model could be described with the use of a simple figure like the works of Battese (1992) and Coelli et al. (2000).

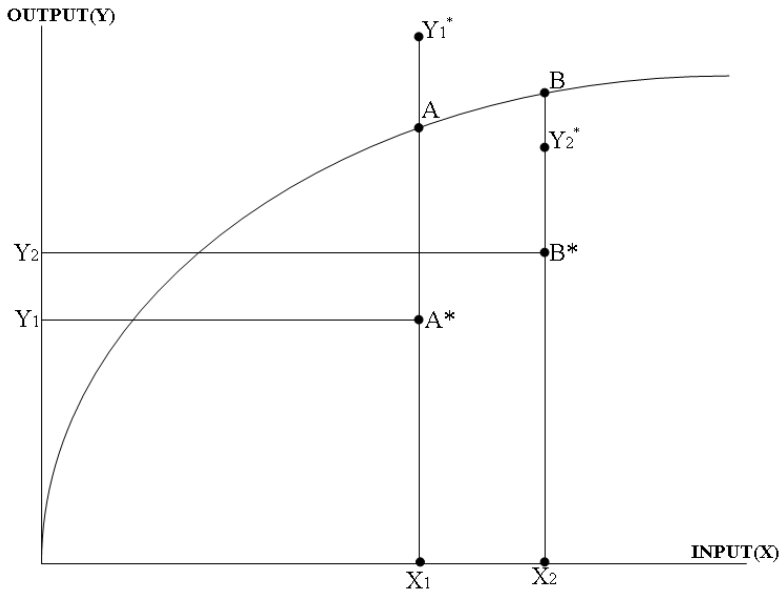


Figure 1. Relationship of Input (X) with Output (Y) in Frontier Function

Figure 1 shows that producer 1 uses X_1 inputs to produce output of Y_1 and producer 2 uses X_2 inputs to produce output of Y_2 . If the producers were fully efficient and there were no stochastic factors influencing their outputs they were categories on deterministic frontier shows at points A and B. Understanding that there was no fully efficient process in agricultural process there may be some uncontrollable stochastic factors positively affect on the output. Therefore under stochastic production function producer 1 and 2 would produce output on Y_1^* and Y_2^* respectively. Reviews of these studies are systematically provided in Battese (1992) and Bravo-Ureta and Pinheiro (1993).

The stochastic frontier production function was proposed by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977). This function was mostly applied in agriculture (Thiam *et al.*, 2001) with model under the work of Cobb-Douglass (1928). Coelli and Battese (1996) specified stochastic frontier production inefficiency model based on Battese and Coelli (1995) proposed to investigate factors affecting the technical inefficiency of Indian farmers. Similarly, Seyoum *et al.* (1998) and Khairo and Battese (2004) have applied the above model to analyse the technical efficiency of maize farmers in Ethiopia. Following the works of these people, the model for specific conditions for dryland farming operations in the northern zone of Lombok is as follows:

$$\ln Y_i = \beta_0 + \sum_{i=1}^n \beta_i \ln X_{ij} + (v_i - u_i)$$

where \ln represents the natural logarithm base e ; the subscript i refers to the i th sample farmer; X_{ij} is the j farm input used by the i th sample farmer¹; v_i is the two-sided noise component and u_i is the non-negative technical inefficiency component of the error term. The noise component v_i is assumed to be independently identically distributed (*iid*) and normally distributed with mean zero and variance σ_v^2 or $N(0, \sigma_v^2)$. v_i is also distributed independently of u_i . The u_i is a non negative error denoting inefficiency of the i -th producer which assumed to half normal (Greene, 1993). Thus the error term $\varepsilon_i = (v_i - u_i)$ is not symmetric because $u_i \geq 0$. Given that the random variable $\varepsilon_i = (v_i - u_i)$ is observable, Jondrow *et al* (1982) could predict u_i by the conditional expectation, $E(u_i | v_i - u_i)$. The farm specific technical efficiency for the i -th farmer sample is given by

$$TE_i = \exp(-u_i)$$

According to Battese and Corra (1977) the parameters of the model are obtained considering the parameter gamma, $\gamma \equiv \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$, which is bounded by 0 and 1, and $\sigma^2 \equiv \sigma_v^2 + \sigma_u^2$ is the variance of the composite error term. If $\sigma_v^2 = 0$ then $\gamma = 1$ means all the differences in error term are the results of controllable factors and if $\sigma_u^2 = 0$ then $\gamma = 0$ means all the differences in error term are the results of uncontrollable factors.

Then the factors affecting farm specific technical efficiency are identified through the regression analysis using the model below.

$$TE_i = d_0 + d_1AGE + d_2EDUC + d_3EXPC + d_4CRDT + d_5LOCT + d_6FAML$$

U_i is the value of technical efficiency for the i -th farmer; AGE is the age of farmer (years); $EDUC$ is education level of the farmer (years); $EXPC$ is the number of years in farming (years); $CDRT$ is the dummy of using credit (1 is

¹ The kind of farm inputs that were used for each commodity cannot be detailed here because inputs used in the cultivation of maize, peanuts and cassava are slightly different.

using and 0 is not using); *LOCT* is the dummy of farm location (1 is far and 0 is near); *FAML* is number of family labour. All parameters in the models are estimated by maximum-likelihood methods using the computer program, FRONTIER version 4.1 written by Coelli (1996).

Result and discussion

The summary statistics of the variables are reported in Table 1. From 227 farmers interviewed all respondent apply fertilisers, seed, bullocks and hired labour but 221 used pesticide. With regards to production, on average farmers produce 39.40 quintals per hectare with standard deviation 8.43. This indicates that there is a large variability of productivity per farmer. This variability due to there is high variability of farm input using among farmers. The yield gap between the average productivity and the lowest is 25.74 quintals. This means there is a room to improve this production process.

Table 1. Statistic value of inputs and output of rice production in dryland farming of Lombok Island, 2005

Variables	N	Mean	SD	Min	Max
Production (Kw/ha)	227	39.40	8.43	12.86	46.67
NPK (Kg/ha)	227	100.64	29.19	22.00	210.57
Seed (Kg/ha)	227	59.98	14.39	26.67	119.05
Pesticide (Rp/ha)	221	20843	5848	7812	40000
Bullock (Hours/ha)	227	82.89	23.07	33.33	200.00
Labours (Hours/ha)	227	822.87	201.75	327.86	1270.00

This average productivity is obtained with the application of some inputs like fertilisers (Urea, SP36 and KCI), seed mostly certified, pesticides, animal labours and total labours. After running some models in the analysis, the best model found was a model under the conversion of fertilisers to be amount of nitrogen, phosphorous and potassium. Average NPK used in survey area is much lower than the local recommended amount 175 kg to 200 kg.

Regarding seed, farmers on average used 59.98 kg per hectare area with range from 26.67 kg to 119.05 kg. This wide range is due to the variability of the seed is very high. Basically, four types of seed distributed in study location: certified seed from commercial breeding industry, certified seed from local breeder, local seed from skilful farmers, and local seed that was produced by farmer. Similarly, pesticides used were also highly varied. Some farmers used pesticide only for the seed, some applied for the seed and plant, and some others applied only for the plants. As a result, the range of pesticide cost is very wide.

With regard to labour, two kinds of labour were used: animal and man labour. This is a typical of dryland where mechanisation is practically difficult to be applied. Comparison between the two, farmers used man labour much more than animal labour (bullock). This is because animal labour is only

involved in soil tillage while man labours used in every step of farm production process including soil tillage. There is no standard recommendation for the amount of this labour per hectare basis.

Table 2. Statistic value of factors determining the variance of farm specific technical efficiency of rice production in dryland farming of Lombok Island, 2005

Items	N	Mean	Mode	SD	Minimum	Maximum
age	227	41.25	25	10.19	25	72
Education	227	5.23	6	2.98	0	12
Experience	227	17.43	20	7.58	4	35
Dummy Credit	227	0.64	1	0.48	0	1
Dummy Location	227	0.50	0	0.50	0	1
Productive labour	227	1.63	1	0.84	1	4

Farmers' age ranged between 25 and 72 years with an average 41 years. This indicates that young generation in dryland areas seem to be interested in running farms. One perceivable reason is probably that the difficulty of seeking jobs for educated people in rural areas.

In terms of education level, majority of respondents (mode) have education of elementary school or less. This is because in 1970s government released program that force people educate their children at least in elementary school. At this decade, government established elementary school in almost every village under president instruction called *SD Inpres*.

Regarding the length of being a farmer, on average the respondents have been farming for 17 years. This means on average farmers started farming in the age about 24 years old. For this item, the farmers were asked about the time when they first ran their farm individually without parental control. The reason of this perhaps because in the village area farmers' parents usually arranged for their children to have their own families at this age. From that time the farmers have to responsible run the farm independently, including making all decision about farming practices.

Credit availability and farm location are also predicted to be determinants of farm specific technical efficiency. Access to formal credit permits a farmer to enhance technical efficiency by overcoming financial constraints for the purchase of higher quality variable inputs, such as fertilizer or new technological package such as high-yielding seeds. If a farmer fails to purchase fertiliser for his standing crop, output loss may be irretrievable. Credit, therefore, can help increase technical efficiency, while credit constraint decreases the efficiency of farmers by limiting the adoption of high-yielding varieties and the acquisition of information needed for increased productivity. There are more farmers who used credit than those who did not. The credit

was available through farmer's cooperative with its amount based on definitive farm requirement from farmer's group leader. In terms of farm location most farmers live near their farm. This is very common in rural areas where farmers live with their family in their farm. The farmers normally used 2 – 4 *ares* of their farm land as their home that used specially to ease of managing their farm. This is called *ngerepoq*.

In terms of family labour, majority of farmers have only one productive labour in their family. This is probably because farmer's children nowadays prefer to continue their study in the city. Moreover, family planning program that promoted intensively 1980s provides rural people only have two children no matter the sex of them.

Table 3. Maximum Likelihood estimates for the parameters of the Cobb-Douglass Stochastic Frontier Model of rice production in dryland farming of Lombok Island, 2005

Variables	Symbol	Coefficient	SE	t-ratio
Intercept	β_0	-1.134	0.236	-4.802
NPK (Kg ha ⁻¹)	β_1	0.182**	0.028	6.518
Pesticide (Rp ha ⁻¹)	β_2	0.010**	0.005	1.919
Seed (Kg ha ⁻¹)	β_3	0.390**	0.039	10.006
Bullock (Hours ha ⁻¹)	β_4	0.046*	0.028	1.660
Labour (Hours ha ⁻¹)	β_5	0.323**	0.039	8.269
Constant	δ_0	1.471	0.823	-1.788
Age (Years)	δ_1	-0.025**	0.014	-1.795
Education (Years)	δ_2	0.029*	0.019	1.542
Experience (Years)	δ_3	0.046**	0.023	1.998
Dummy Credit	δ_4	-0.217**	0.123	-1.756
Dummy Location	δ_5	-0.607**	0.271	-2.241
Family labour (Person)	δ_6	-0.436**	0.186	-2.341
Sigma square	σ^2	0.264	0.118	2.237
Gamma	γ	0.976	0.013	76.974

The maximum-likelihood of the parameters for Cobb-Douglass frontier production function for rice cultivation were given in Table 3. The estimated coefficients generally have the expected signs. All independent variables have positive coefficients and measure elasticities of rice production with respect to inputs applied. Three main inputs – seeds, labours and fertilisers – have elasticity of 0.390, 0.323 and 0.182 respectively. This implies that paddy output has high respond to changes for an additional unit of these three inputs. In other words, there is scope for increasing production of rice by increasing the level of these inputs. For example, 10 percent increase of seeds per hectare with other inputs do not change, paddy output will increase 3.9 percents. This means that if each of these three inputs increases 10 percent per hectare with other inputs do not change, paddy output will increase 8.9 percents.

This situation is understandable because certified seeds and fertilisers (Urea, SP36 and KCl) as the most important inputs of rice production were not readily available at right time and at affordable cash prices to rice farmers in the area of the study. If farmers want to obtain certified seeds and fertilisers at the exact time when required, the farmers have to purchase these inputs in cash in private traders. However, most rice farmers in research areas were still dependence on governmental credit scheme. The policy implication is that it is imperative for the government to continue its efforts to provide certified seeds and inorganic fertilisers at affordable prices and at a right time.

In terms of labours, southern of Lombok where this research conducted is popularly known as migrant workers supplier. Migration and urbanisation of this labour force was felt by farming sector of this area specifically when harvesting time. In rice cultivation, harvesting is the step that absorbs the highest amount of labours. Therefore, in study area rice cultivation process as a whole still required additional labours to increase its efficiency.

Regarding application of pesticide and bullock, the model also informs that these two kinds of input significantly influence rice farm productivity at 5 percent level of error. This means that the changes of pesticide and bullock may have potential opportunity to increase rice farm productivity. This situation due to the habit of farmers that apply pesticide when there is a sign of pest. Hardly farmers use pesticide to prevent the attack of pest and disease. Farmers do not know the kinds and dose of pesticide that can be used to protect their rice farm. Moreover, the price of pesticide is relatively higher than other inputs. Similarly, the usage of bullock is still low. This is because the nature of land is hard when rain has not come yet and sticky in wet season. This situation leads to high rate of bullock price because the bullock need longer time to tillage a hectare of this land compare to common irrigated land.

The distribution of farm specific technical efficiency of dryland rice farm is described in Figure 2. Great variation occurs in the level of efficiency with range from 26.57 percent to 99.81 percent. The average level of efficiency is 86.75 percent indicates that on average rice production process can be increased 13.25 percent to reach maximum possible level. In other words, there is possible effort to increase rice production in research area by an average of 13.25 percent by adopting technology to obtain best performance. Despite majority (72.2 percent) of farmers belonged to the most efficient category (over 90 percent) more that 10 percent of farmers are in least efficient category. This last group really need a significant improvement to reach maximum production level.

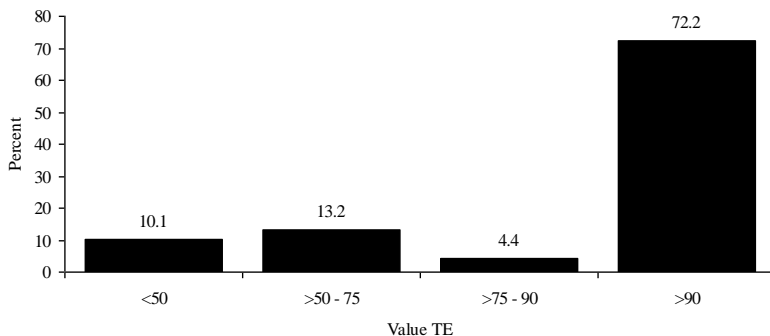


Figure 2. Distribution of TE of Rice Farming in Dryland of Lombok Island

In terms of factors affecting the level of farm specific technical efficiency, all six tested variables are statistically significant to explain the variation of the efficiency. Kumbhakar and Bhattacharya (1992), Ali and Chaudry (1990) state that socio-economic, demographic factors, farm characteristics, environmental factors and non-physical factors are likely to affect the efficiency. The variable age of farmers was negatively and significantly correlated with technical efficiency indicating that as the older the farmers the less efficient the use of farm inputs to produce rice. As the age increases farmers become more risk averters and hesitate to adopt new technologies making the production process less efficient. Another reason for this is probably because the age variable picks up the effects of physical strength. Although farmers become more skilful as they grow older, the learning by doing effect is attenuated as they approach middle age, as their physical strength starts to decline (Liu and Zhung, 2000; Abdulai and Huffman, 1998).

The rate of technical efficiency increases significantly with the increase of schooling years of farmers. This means that farmers with higher education level carry out farm production process in more efficient manner. This is understandable because well-educated farmers can understand production technology better. Moreover they can get information from various sources and can maintain better relationship with extension workers or information agencies. This finding is consistent with the result of Abdulai and Eberlin (2001) found that education level can significantly increase farm specific technical efficiency in Nicaragua during economic reform. Similarly, Seyoum *et al* (2000) reported that in Eastern Ethiopia maize farmer with more education respond more readily to new technology adoption and produces closer to the frontier output. Doraiswamy (1992) also found that at least middle level school education is required to have significant impact on farm productivity.

Farmers run their farm based on their experience in production of rice. Analysis regression revealed that the difference of farmers experience statistically significant in the impact of the level of technical efficiency. This variable was positively correlated with farm specific technical efficiency that was statistically significant. This may be due to the farmers with high experience will normally more careful in conducting every step of farm production activities.

The availability of credit will lose the constraints of production facilitating to get the inputs on a timely basis and hence is supposed to increase the efficiency of the farmers. In accordance with this expectation the variable is positively and statistically significant at 5 percent level. This suggests that the provision on credit is an important factor for attaining a higher level of technical efficiency. Technically inefficient farmers can possibly get more efficient in the short run by facilitating access to credit scheme.

The value of farm specific technical efficiency was also significantly affected by the location of farm. The result shows that dummy location negatively and significant correlate with the level of technical efficiency. This indicates that the further the farm location the higher technical efficiency reached. This is logic because farmers that run farm in far away location will spend more time and resources to manage every step of production activity.

Number of family labour also significantly influenced the level of technical efficiency. Analysis regression show that increase farm workers in the family brought a decrease of technical efficiency in rice production. This is probably due to the fact that farmers are already using excess human labour in rice production. Moreover, alternative employment opportunities for farm labour in this village are very limited. Hence human labour utilisation increases with increase in the number of farm workers in the family. As a consequence, this will increase the inefficiency of the farm production process.

Maximum likelihood for the variance parameter γ for farmers was 0.976 corrected to three digits behind the decimal place indicating that the random error v_{it} is effectively zero. This suggests that frontier production function is better in a form of deterministic than stochastic. This result is honestly contrary to expectation because theoretically the random errors and data noise plays a significant role in influencing agricultural production. Therefore ideally this analysis required the Generalized Likelihood Ratio test for every parameter in the function. However, due to limitation of time and resources this test cannot be performed in this study.

Conclusion

This study set out to provide estimates of technical efficiency in the rice production and to explain variations in technical efficiency among farms

through managerial and socio-economic characteristics. Yield of rice can be considerably improved with increasing the level of inputs in the study area if the efficiency is increase. Results show that the overall mean technical efficiency is on average 86.75 percent. Therefore, there is a 13.25 percent scope for increasing rice production by using the present technology. However, TE ranges between 26.57 to 99.81 percent among the rice producers in dryland farming of Lombok. The model also provides information that all five variables – NPK fertilizers, pesticide, seed, bullock and labour – positively and significantly influence the level of land productivity in rice production. Therefore, the improvement of rice production in dryland areas of Lombok can be conducted with increasing the use of all farm inputs above. Clearly, as noted by Kibaara (2005), the explanatory variables included here, although indicating the importance of management factors, do not fully capture the extent to which management can explain variation in technical efficiency of rice production.

Technical efficiency in production of rice is negatively related to age of farmer, provision of credit, the distance of farm location and the number workers in farmer's family. Years of schooling and the length of farmers managing farm independently positively and significantly affected the level of farm specific technical efficiency. This means that technical efficiency can be increased through improving the schooling or education opportunity of farmers in the village. Moreover, the scheme of credit must also need to be reviewed regarding both the volume and the system. Future studies could probably include variables that address the gender issue in rice production rather than the assumption that the household head is the decision maker in farm decisions. In addition, a quantification of number of visits by an agricultural extension agent and field level soil type could improve the precision of measurement of technical efficiency. This study focused on technical efficiency only, but a study on allocative efficiency would probably give more insight to the efficiency studies.

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