

Environmental Efficiency Analysis on Rice Production in Ciamis Regency: Agricultural Economic Development Perspective

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ABSTRACT

The aim of this study is to analyze the value of environmental efficiency on rice production which is influenced by labor, seeds, organic fertilizers, organic pesticides, chemical fertilizers and chemical pesticides. This study was carried out in paddy fields in Kertarahayu Village, Pamarican District, Ciamis Regency, West Java Province, Indonesia with a sample of 50 farmers obtained by the method deep interview. This study uses a stochastic frontier approach with cross section data. The results of this study indicated that the most significant influence on the environmental efficiency of rice production in Ciamis Regency is ZA fertilizer. From the results of the environmental efficiency index analysis, it can be seen that Ciamis Regency has a gamma value of 0.00263. This means that Ciamis Regency has a small environmental inefficiency value (<1).

Keywords: agricultural development, environmental efficiency; production input; stochastic frontier, Ciamis

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1. Introduction

Nowadays the attention on environmental sustainability and natural resource management is getting bigger. Attention to the environment and its sustainability are the main priorities to be developed, including in the case of sustainable agricultural development. Agricultural development can also be said as economic development in the agricultural sector, because agriculture is one of the sectors in economic life. In addition, the notion of agriculture itself also contains economic elements, because agriculture is a human endeavor through the life of plants, animals and the natural environment, so that humans are able to meet their daily needs (Sudrajat, 2018).

Indonesia is a vast archipelago with a large population. The implication of the large population is the provision of food, especially rice as a daily food staple (Sudrajat, 2019a). During the 1960s, Indonesia experienced a shortage of food, especially rice as a staple food. At that time rice was difficult to obtain and the price was relatively expensive, not comparable with population growth. Therefore at that time it was called a difficult period or a scarcity of food.

In the 1970s the Indonesian government began to think of concrete steps to overcome the danger of food shortages, especially rice by implementing agricultural technologies and innovations within the framework of a green revolution. The green revolution is a process of transformation from traditional agriculture to modern agriculture (Manning, 1988). The green revolution comes by implementing agricultural technology and innovation using chemical fertilizers and pesticides as well as high yielding varieties to produce abundant rice harvests (Sasson, 1990).

In the decade of the 1990s to 2000s, the negative impact of the use of fertilizers, seeds and chemical pesticides began to be felt by farmers with the destruction of biodiversity and soil biology. It is also followed by a high dependency of farmers on fertilizers, genetically modified seeds, the destruction of local rice varieties, the presence of pesticides that cause immunity against some rice pests, and the destruction of beneficial pest predators for farmers (Sutanto, 2002).

The importance of this research is to analyze the most dominant factors affecting environmental damage, so that the use of chemical fertilizers and pesticides used by farmers can be reduced. The specific specification of the relevance of this research to the applied research scheme is to obtain a solution to the problem of the many uses of chemical fertilizers and pesticides on the environment and human health. If not taken seriously, this could affect the economic development of agriculture in Ciamis Regency.

2. Literature Review

Widodo (2011) states that agricultural development policies are expected to contribute to driving economic development. This can be seen in the development of development economics which plays a role in academic studies to see the extent of the development of economic development in the history of its development. Agricultural development has an interest in agricultural change in relation to the welfare of the community economically and socially within the framework of agricultural economic development in an area. This is related to what kind of farming system is used.

Farming efficiency can be in the form of technical efficiency, allocative efficiency, economic efficiency, and environmental efficiency (Mkhabela, 2011). Environmental efficiency is a type of additional efficiency (Reinhard et al., 1999). Inputs used in the production process can have positive or negative impacts on the environment, so there is a need to measure environmental efficiency. Measurement of environmental efficiency aims to consider the impact of the use of inputs that have the potential to affect the environment on economic units according to their level of efficiency.

Research on environmental efficiency was initiated by research from Reinhard (1999) which analyzed the economic and environmental efficiency of dairy farming in the Netherlands econometrics based on neoclassical production theory. Zhang & Xue (2005) analyze and estimate environmental efficiency in vegetable production in China. Waryanto et al. (2015) conducted a study by estimating environmental efficiency with a detrimental variable onion product input using the stochastic frontier analysis (SFA) approach.

Researches, both on organic and conventional rice farming, are currently examining more technical efficiency with a stochastic frontier production function approach as conducted by Putra & Tarumun (2012); Kadiri et al. (2014); Murniati et al. (2014); Heriqbaldi et al. (2015); Sudrajat (2019a). In addition to technical efficiency, there are also studies of allocative efficiency or cost efficiency in production with a stochastic frontier approach, as conducted by Hidayah et al. (2013); Ghosh & Raychaudhuri (2015); Ajoma et al. (2016); Rathnayake & Amaratunge (2016); Sudrajat et al. (2018). In addition to technical efficiency or allocative efficiency, there are also studies of economic efficiency or benefits with a stochastic frontier approach, such as those conducted by Mailena et al. (2014); Adamu & Bakari (2015); Kaka et al. (2016); Chang et al. (2017); Sudrajat et al. (2017). In addition to technical efficiency, allocative efficiency or profit efficiency, there are also several agricultural studies that discuss the behavior of farmers in facing the risk of rice production, both organic and inorganic rice, as conducted by Binswanger (1980); Ahyar et al. (2012); Zakarin et al. (2013); Suharyanto et al. (2015); Sudrajat (2019b).

However, there are still some organic or inorganic rice researchers who estimate environmental efficiency (in addition to technical, allocative and economic efficiency) with a stochastic frontier approach. Several conventional rice studies that estimate environmental efficiency were conducted by Van Hoang & Yabe (2012); Hoang & Nguyen (2013); Hossain et al. (2013); Saelee (2017). Organic rice research that estimates environmental efficiency with a stochastic frontier approach is still very limited in number compared to conventional rice. Guo & Marchand (2012) conducted a study by estimating environmental efficiency in non-certified organic rice production in China. Prihtanti (2015) conducted a study of several studies in Indonesia by estimating the efficiency of organic and conventional rice production as well as environmental efficiency with stochastic frontier approach.

3. Theoretical Framework

3.1 Concept of efficiency in agriculture

The ability of the agricultural sector to produce agricultural products depends on the level of farm income and the resulting surplus. The level of farm income is an important factor to support economic growth in general and is a major determinant of farmers' welfare in particular (Adiyoga, 1990). The level of farm income is determined by the efficiency of farmers to allocate their resources to various alternative production activities. If farmers do not use these resources efficiently, there will be an untapped potential to increase farm income and create a surplus. Therefore, the identification of efficient use of resources is an important issue that determines the existence of various opportunities in the agricultural sector related to its contribution to economic growth and improving farmers' welfare (Weersink et al., 1990).

Measurement of efficiency begins with the concept put forward by Farrel (1957) which defines efficiency as the ability of a company or farm to produce maximum output with the use of a certain number of inputs. Doll & Orazeem (1984); Debertin (1986) defines efficiency as the maximum amount of output achieved by the use of a certain number of inputs or to produce a certain number of outputs that use the smallest possible input. Kumbhakar & Lovell (2000) measure efficiency as the level of success of a manager in allocating available inputs and outputs in achieving goals and achieving the highest level of efficiency in costs, revenues and profits.

3.2 Measuring the level of environmental efficiency

Reinhard (1999) stated that stochastic frontier analysis (SFA) was originally initiated by Aigner, Lovell and Schmidt in 1977. SFA is an econometric method that is used to calculate the efficiency of certain input uses. Farmer production is said to be efficient if the level of production from a farmer is higher than the limit of the best level of production. To this function a non-negative random variable (U_i) is added to capture inefficiencies such as farmer education level, farmer age, and how long to be a farmer, so that the general SFA form for one input variable can be written in equation 1 as follows:

$$Y_i = f(X_i; \beta) \times \exp\{V_i - U_i\} \quad (1)$$

where Y_i is the level of production, X_i is the input variable used, β is the parameter to be predicted, V_i is a random variable that is related to external factors such as climate and pests as well as its symmetrical distribution and normal spread, and U_i is the random variable non-negative factors that affect the level of inefficiency and are related to internal factors and are assumed to be half-normal spread. Reinhard (1999) applies SFA by adding one variable which is considered detrimental to the environment (detrimental input) which aims to get the value of environmental efficiency. According to Reinhard (1999) the general form of SFA can be written in equation 2 as follows:

$$Y_i = f(X_i; Z_i; \beta) \times \exp\{V_i - U_i\} \quad (2)$$

Equation (2) is the same as equation (1), except there is an additional factor of Z_i, which is the input variable which is considered detrimental to the environment (detrimental input). With the translog production function, the complete model can be stated (Reinhard, 1999) in equation 3 as follows:

$$\ln Y_i = \beta_0 + \sum_j \beta_j \ln(X_{ij}) + \beta_z \ln(Z_i) + 0.5 \sum_j \sum_k \beta_{jk} \ln(X_{ij}) \ln(X_{ik}) + \sum_j \beta_{jz} \ln(X_{ij}) \ln(Z_i) + 0.5\, \beta_{zz}(\ln Z_i)^2 - u_i + v_i \quad (3)$$

where i = 1, ..., n is the 1st farmer to the nth farmer, j, k = 1,2, ..., p is the input variable used, ln (Y_i) is the logarithm of the output of farmers to i, ln (X_{ij}) is the logarithm of the input variable to j used by the farmers to i, ln (Z_i) is the logarithm of the input variable which is considered to damage the environment by farmers to i, u_i is a non-negative random variable, and affects the level of inefficiency and is related to internal factors and is assumed to be half-normal spread ($u_i \sim |N(u,\sigma_u^2|)$, v_i is a random variable related to external factors (climate, pests), the distribution is symmetrical and spread normally ($v_i \sim N(0,\sigma_v 2)$), also β_j, β_z, β_{jk}, β_{jz}, β_{zz} are the parameters to be estimated.

Reinhard (1999); Mkhabela (2011); Guo & Marchand (2012) formulated environmental efficiency in equation 4 below:

$$\ln EE_i = [-(\beta_z+\Sigma\beta_{jz}\ln X_{ij}+ \beta_{zz}\ln Z_i) \pm \{(\beta_z+ \Sigma\beta_{jz}\ln X_{ij}+ \beta_{zz}\ln Z_i)^2\ 2\beta_{zz}U_i\}^{0.5}]/\beta_{zz} \quad (4)$$

where lnEEi is the environmental efficiency of the i-th farmer, X_{ij} is the variable of farmer input, Z_i is the detrimental input of the i-th farmer, U_i is the inefficiency factor, and β_z, β_{jz}, β_{zz} are the parameters to be estimated. Reinhard et al. (1999) states environmental efficiency is basically one aspect of technical efficiency because it focuses on one input that has negative consequences on the environment. This measurement is then a non-radial input oriented measurement because only one of the many inputs is examined. The decrease in the level of pollution input will have an impact on both technical efficiency and environmental efficiency.

4. Data and Methodology

4.1 Sample and research place

In this research, 67 inorganic rice farmers were interviewed in depth. After interviews, 50 samples of farmers were determined who met the requirements. They are members of the Minaharjasari Farmers Group, Kertarahayu Village, Pamarican District, Ciamis Regency, West Java Province, who have more than 10 years of experience processing rice plants. This research was conducted from September to November 2023 in Kertarahayu Village, Pamarican District, Ciamis Regency, West Java Province, Indonesia.

4.2 Data analysis

Stochastic frontier translog model can be used to estimate the technical efficiency of rice production with the equation: $Y_i = f (X_i, \beta) \exp \{V_i-U_i\}$. Based on the estimated frontier and the level of technical inefficiency the equation is obtained: ($TE = Y_i/[f (X_i, \beta) \exp \{V_i\} = \exp \{-U_i\}$ was used the developed method to estimate environmental efficiency (Reinhard et al., 2000).

The Cobb-Douglas function does not add any new information to the analysis of environmental efficiency. For this reason the translog production function is used to estimate environmental efficiency (Reinhard et al., 2002) in equation 5 below:

$$\ln Y_i = \beta_1\ln X_1 + \beta_2\ln X_2 + \beta_3\ln X_3 + \beta_4\ln X_4 + \beta_5\ln X_5 + \beta_6\ln X_6 + 0{,}5\beta_{11}\ln 2X_1 + 0{,}5\beta_{22}\ln 2X_2 + 0{,}5\beta_{33}\ln 2X_3 + 0{,}5\beta_{44}\ln 2X_4 + 0{,}5\beta_{55}\ln 2X_5 + 0{,}5\beta_{66}\ln 2X_6 + \beta_{12}\ln X_1\ln X_2 + \beta_{13}\ln X_1\ln X_3 + \beta_{14}\ln X_1\ln X_4 + \beta_{15}\ln X_1\ln X_5 + \beta_{16}\ln X_1\ln X_6 + \beta_{23}\ln X_2\ln X_3 + \beta_{24}\ln X_2\ln X_4 + \beta_{25}\ln X_2\ln X_5 + \beta_{26}\ln X_2\ln X_6 + \beta_{34}\ln X_3\ln X_4 + \beta_{35}\ln X_3\ln X_5 + \beta_{36}\ln X_3\ln X_6 + \beta_{45}\ln X_4\ln X_5 + \beta_{46}\ln X_4\ln X_6 + \beta_{55}\ln X_5\ln X_6 + (V_i - U_i). \quad (5)$$

where:

Y_i = the total value of the output for i year of agriculture

X_1 = labor input for i year of agriculture

X_2 = seed input for i year of agriculture

X_3 = organic fertilizer input for i year of agriculture

X_4 = organic pesticides input for i year of agriculture

X_5 = chemical fertilizer input for i year of agriculture

X_6 = chemical pesticides input for i year of agriculture

For each input X_i (i = 1, 2,..., 5) there is an appropriate output elasticity which is explained as a variation of the percentage of the output value for each 1% change in the i year input factors. In the Cobb-Douglas production function, the estimated parameter is the output elasticity itself, while in this study the production translog function, the output elasticity differs from the estimated parameter and is calculated using a total differential to estimate the translog function. According to Reinhard et al. (2002) its deduction function can be stated in equation 6 as follows:

$$әY/Y = (әX_1/X_1)\ (\beta_1+\beta_{11}\ln X_1+\beta_{12}\ln X_2+\beta_{13}\ln X_3+\beta_{14}\ln X_4+\beta_{15}\ln X_5+\beta_{16}\ln X_6) \quad (6)$$

The environmental efficiency index is the ratio of minimum visibility to the observed inputs that are detrimental to the environment: EE = min{Ø:f (X,ØZ) ≥Y} ≤ 1. Where f (X, ØZ) is a frontier function, X is a vector of inputs, Z is a vector of environmental determinant inputs and Y is the value of the output. To produce an environmental efficiency index, a new frontier function can be generated by replacing the observed Z input with θZ and $U_i = 0$. To make the development of new functions come from the original or old translog function, if there is only one input that damages the environment, for example X_6 as the only input that damages the environment (Reinhard et al., 2000), so the results can be written in equation 7 as follows:

$$0{,}5\beta_{66}(\ln ØZLnZ)^2+[\beta_6+\beta_{16}\ln X_1+\beta_{26}\ln X_2+\beta_{36}\ln X_3+\beta_{46}\ln X_4+\beta_{56}\ln X_5+\beta_{66}\ln Z](\ln ØZ-\ln Z)+U_i = 0 \quad (7)$$

Because lnEE = lnØ = ln (ØZ-lnZ, the above function can be written in equation 8 as follows:

$$0{,}5\beta_{66}(\ln EE)^2+[\beta_6+\beta_{16}\ln X_1+\beta_{26}\ln X_2+\beta_{36}\ln X_3+\beta_{46}\ln X_4+\beta_{56}\ln X_5+\beta_{66}\ln Z]\ln EE+U_i = 0 \quad (8)$$

The equation can be solved in equation 9 below:

$$\ln EE = \{-[\beta_6+\beta_{16}\ln X_1+\beta_{26}\ln X_2+\beta_{36}\ln X_3+\beta_{46}\ln X_4+\beta_{56}\ln X_5+\beta_{66}\ln X_6+ \beta_6+\beta_{16}\ln X_1+\beta_{26}\ln X_2+\beta_{36}\ln X_3+\beta_{46}\ln X_4+\beta_{56}\ln X_5+\beta_{66}\ln X_6[\beta_{66}\ln X_6]^2-2\ \beta 6_6U_i]^{0,5}\}/\beta_{66} = 0 \quad (9)$$

If there are 2 inputs that damage the environment (detrimental input), for example: X_5 and X_6 as two inputs that damage the environment (Reinhard et al., 2002), the results can be written in equation 10 as follows:

$$(0{,}5\beta_{66}+0{,}5\beta_{55}+\beta_{56})\ln 2EE+[\beta_5+\beta_{15}\ln X_1+\beta_{25}\ln X_2+\beta_{35}\ln X_3+\beta_{45}\ln X_4+\beta_{55}\ln X_5+\beta_{56}\ln X_6+\beta_5+\beta_{15}\ln X_1+\beta_{25}\ln X_2+\beta_{35}\ln X_3+\beta_{45}\ln X_4+\beta_{55}\ln X_5+\beta_{56}\ln X_6+\beta_6+\beta_{16}\ln X_1+\beta_{26}\ln X_2+\beta_{36}\ln X_3+\beta_{46}\ln X_4+\beta_{56}\ln X_5+\beta_{66}\ln X_6)\ln EE + U_i = 0 \quad (10)$$

This equation can be solved in equation 11 below:

$$\ln EE = \{-(\beta_5+\beta_{15}\ln X_1+\beta_{25}\ln X_2+\beta_{35}\ln X_3+\beta_{45}\ln X_4+\beta_{55}\ln X_5+\beta_{66}\ln X_6+\beta_6+\beta_{16}\ln X_1+\beta_{26}\ln X_2+ \beta_{36}\ln X_3+\beta_{46}\ln X_4+\beta_{56}\ln X_5+\beta_{66}\ln X_6)^2-4(0{,}5\beta_{66}+ 0{,}5\beta_{56}+0{,}5\beta_{55})U_i]^{0,5}\}/(\beta_{66}+\beta_{55}+2\beta_{45}) \quad (11)$$

In this function, "+ √" is included in the model because if Ui = 0, only when "+ √" is used, lnEE is equal to "0". Therefore in this model, the environmental efficiency index can be calculated using the formula EE = exp (lnEE) = Ø = (ØZ)/Z, where Ø is an environmental efficiency index. To estimate the stochastic frontier function on the environmental efficiency index software 4.1 can be used (Coelli, 1996).

5. Results and Discussion

In this study rice production in Kertarahayu Village, Pamarican District, Ciamis Regency was influenced by several production input variables, namely: labor, seeds, urea fertilizer, phonska fertilizer, and ZA fertilizer. These variables are used to see the extent of its influence in inorganic rice production and furthermore what effect it has on the environment, especially on environmental efficiency. The description of the results of research in Ciamis

Regency shows that the variable of labor has a negative effect on production at a significance level of 99%. The variables that have a positive effect on production at the significance level of 5% and 1% are the variable phonska fertilizer and ZA fertilizer. This means, if both fertilizers increase by 1%, then rice production will also increase by 0.080539 and 2.355543. In this study, the input variable of production which had the most significant effect was the ZA fertilizer variable. The results of the study in Ciamis Regency can be seen in Table 1.

Tabel 1. Estimation result of factors causing environmental inefficiency in Ciamis Regency

Variable	Parameter	Coefficient	Standard Error	Z	P>|Z|
Labor	X_1	-1.843039	0.522072	-3.53	0.000
Seed	X_2	0.0781755	0.157934	0.49	0.621
Urea fertilizer	X_3	0.0268928	0.0189927	1.42	0.157
Phonska fertilizer	X_4	0.080539	0.0343519	2.34	0.019
ZA fertilizer	X_5	2.355543	0.5351164	4.4	0.000
Constant		31.52238	5.853041	5.39	0.000
$\ln Sigma^2 v$		-1.211934	0.214965	-5.64	0.000
$\ln Sigma^2 u$		-7.129913	80.25636	-0.09	0.929
Sigma v		0.5455446	0.0586367		
Sigma u		0.0282982	1.135556		
Sigma-square		0.2984219	0.0723069		
Lambda		0.0518713	1.158202		
Number of obs.		50			
Sigma u		0.028			
Sigma v		0.545			
Gamma		0.00263			

(Source: Primary data analysis, 2024)

Based on the table of gamma value analysis results, it can be seen that Kertarahayu Village, Pamarican District, Ciamis Regency has a gamma or inefficiency value of 0.00263. This shows that Ciamis Regency is experiencing environmental degradation or in other words there is a contribution of agricultural inputs, namely chemical fertilizers and pesticides to environmental pollution. The higher the inefficiency value, the greater the contribution of chemical fertilizer and pesticide inputs to environmental degradation. The large amount of inefficiency has an impact on environmental degradation. The supporting factor for environmental degradation is influenced by the high number of farmers who use chemical fertilizers and pesticides in Ciamis Regency.

Behind the pride of a region in creating high economic growth, the lure of catching up with other regions actually gives birth to new problems that are increasingly complicated and prolonged, both in the long term and short term. The problem of environmental degradation lately is very clear to us. In ancient times people were so easy to enjoy the beauty of nature, the coolness of clean water in rivers and the beauty of the vast mountains and agriculture that was not contaminated with chemicals. But now it is very rare for modern humans to enjoy the natural beauty and environmentally friendly agricultural products.

Seeing the condition of agricultural nature that has been increasingly damaged, because it is polluted by chemicals, presumably need concrete steps to deal with this. This is certainly related to economic development programs in each region. Economic development should still pay attention to three dimensions, namely ecology, economics and social. All three are included in the sustainable agricultural economic development. Restrictions on the use of chemical fertilizers as in Minister of Agriculture Regulation No. 40/Permentan/OT.140/4/2007 concerning recommendations for fertilizing N, P, and K on site-specific lowland rice will provide balance in the agricultural environment and increase the economy of the surrounding area.

If not realized, macroeconomic and sectoral policies have played an important role in creating environmental damage. Agricultural economic development policies, finance, development programs, etc. have an effect on the resource base. The government and entrepreneurs should find a win-win solution in linking policies that lead to the exploitation of natural resources, especially agricultural nature, with the ability of the environment to create balance. There should be a social contract between all parties in preserving the environment and the balance of the ecosystem that is in it between the government and agricultural businesses. From the perspective of agricultural economic development it can be emphasized about the balance of nature. The hope is that agricultural output can increase, but environmental sustainability is maintained, for the benefit of future generations.

6. Conclusion

Nowadays environmental efficiency, as an additional type of efficiency, can be provided, is increasingly important. Inputs used in the production process can have both positive and negative impacts on the environment. From the environmental efficiency index obtained from an agricultural area, it can be seen how far the agricultural area has an influence or impact on the degradation of the surrounding environment. This is certainly related to economic development policies in the region.

From the research results it can be concluded that the variable that has the most significant influence on the environmental efficiency of rice production in Kertarahayu Village, Pamarican District, Ciamis Regency is ZA fertilizer. From the results of the environmental efficiency index analysis, it can be seen that Ciamis Regency has a gamma value of 0.00263. This means that Ciamis Regency has a small environmental inefficiency value (<1). The lower the environmental inefficiency value in an area, the smaller the contribution of chemical fertilizer and pesticide inputs to environmental degradation in that area. Areas experiencing severe environmental degradation need to implement policies to restore their environment from damage caused by environmental pollution or the large use of chemical fertilizers.

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