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TECHNICAL EFFICIENCY OF SHALLOT PRODUCTION IN PRODUCTION CENTERS IN JAVA AND OUTSIDE JAVA

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ABSTRACT

To increase shallot production in Indonesia is faced with the issue of the dichotomy between Java and outside Java. Data shows that more than 70% of shallot harvested area is on Java, even though it is only 17% of Indonesia's total agricultural area. This research aims to identify factors that determine shallot production and measure the technical efficiency of shallot production and its determining factors. We used survey data from the Central Bureau of Statistics in 2014, which consisted of 2,860 input-output units of shallot production on Java and 940 outside Java. Using the stochastic frontier production function, it is found that production factors of land, labor, seeds, fertilizers and pesticides significantly determine shallot production in Java and outside Java. The marginal productivity of land, labor, seeds, fertilizers and pesticides in Java is higher than outside Java. The average technical efficiency score of production outside Java is higher than in Java. However, land productivity outside Java is lower than in Java. These findings indicate that the majority of shallot farming outside Java is already at its production frontier, whereas in Java only a small portion has reached its production frontier. Technical efficiency of production is determined by season and type of land, as well as farmers' membership in farmer groups, partnerships, and cooperatives. This conclusion implies that increasing shallot production outside Java requires new technology that can increase marginal input productivity. Technology to be developed is the use of true shallot seeds, accompanied by irrigation and agricultural institutions.

Keywords: *Java, outside Java, shallot production*, *stochastic frontier analysis, technical efficiency*

BACKGROUND

Shallot in Indonesian is a high-value horticulture commodity because it is widely used by households and the food industry. More than 90% of Indonesia's population are consumers of shallot. Furthermore, shallot is widely used in the food industry as a seasoning and flavoring. Therefore, the demand for shallots in Indonesia tends to increase in line with the increase in population and the development of the food industry. Shallots also have an important role in the national economy. It contributed around 8.31% to the Gross Domestic Product (GDP). Shallot is also one of Indonesia's important trading commodities. In the year 2022, shallot exports reached US$ 4.18 million and imports amounted to US$ 1.49 million. Even though imports increased by more than 80%, the trade balance is still in surplus (BPS 2022).

The trade surplus indicated that from the supply side significant portion of Indonesia's shallot comes from domestic production. In 2022, shallot production reached 1.4 million tons, and over the last 10 years (2010-2022), the production has grown by 4% per year. In the same period, it was

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revealed that the growth of the harvest area reached 6per year but the productivity growth (ton/ha) was only 0.4% per year. This indicated that the growth in shallot production in Indonesia was basically due to the expansion of planting areas, not productivity.

Shallots are a tropical plant that technically can grow in all the islands of Indonesia. However, at least in the last 10 years, more than 70% of Indonesia's shallot harvest area has been in Java Island. This is interesting because the agricultural area on Java Island is only around 18% of Indonesia's total agricultural area (Table 1). This phenomenon often creates a dichotomy between Java and outside Java in various contexts, including the development of shallot areas in Indonesia. For example, in the strategic planning document of the Directorate General of Horticulture, it was stated that in 2020-2024 shallots will be developed outside Java Island. This development plan of shallot was called a new era of national shallot supply. Historically the dichotomy of Java and outside Java are (1) the farmland in Java Island is generally known as more fertile compared to that of outside Java, (2) agricultural and non-agricultural infrastructure in Java is better than in outside Java, and (3) the socio-cultural conditions of the farmer communities in Java differ from those in outside Java.

The differences in agricultural land fertility between Java and outside Java are often described by differences in land productivity (yield, ton/ha). In Table 1, it can be seen that initially, shallot productivity on Java Island was higher compared to outside Java Island. However, subsequent developments indicate an increase in productivity outside Java Island, especially in the last three years, where productivity outside Java Island has surpassed that of Java Island. The increase in shallot productivity outside Java Island is a positive indication for the government in their efforts to boost shallot production in Indonesia by expanding cultivation areas outside of Java.

Table 1. Harvested areas and yield of shallot, and agriculture land areas in Java Island and Outside Java Island

Year	Java Island			Outside Java		
	Harvested Area (Ha)	**%**	**Yield (Ton/Ha)**	**Harvested Area (Ha)**	**%**	**Yield (Ton/Ha)**
2010	86,309	78.72	9.81	23,325	21.28	8.67
2011	68,033	72.63	10.09	25,634	27.37	8.05
2012	70,926	71.27	10.34	28,593	28.73	8.06
2013	75,097	75.90	10.51	23,840	24.10	9.28
2014	90,912	75.32	10.52	29,792	24.68	9.31
2015	86,888	71.15	10.21	35,238	28.85	9.71
2016	105,006	70.17	9.58	44,629	29.83	9.89
2017	106,154	67.11	9.09	52,018	32.89	9.72
2018	104,862	66.89	9.50	51,917	33.11	9.77
2019	108,591	68.21	9.96	50,604	31.79	9.85
2020	130,070	69.59	9.62	56,830	30.41	9.94
2021	128,905	66.25	9.83	65,670	33.75	11.23
2022	86,309	78.72	9.81	23,325	21.28	8.67
Average		70.84	9.93		29.16	9.67
Agric. Land Area	6,521,095	17.71		30,295,991	82.29	

Source: BPS Dynamic Table, Directorate of Horticulture (2020)

Based on the facts and issues outlined above, it is important to conduct an in-depth

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investigation into shallot production on Java Island and Outside Java Island. Research questions that need to be answered include: (1) To what extent does the dichotomy between Java Island and Outside Java Island determine shallot production in both regions?, (2) What are the production factors affecting shallot production on Java Island and Outside Java Island?, (3) How does the technical efficiency of shallot production on Java Island compare to that of Outside Java Island?, (4) What are the determining factors of technical efficiency in shallot production in Java Island and Outside Java Island?. This research specifically aims to: (1) identify the factors influencing shallot production on Java Island and Outside Java Island, (2) measure the technical efficiency of shallot production in both regions, and (3) identify the factors influencing the level of technical efficiency in shallot production in the two regions. This research will provide deeper insights into the economy of shallot production in Indonesia and help formulate more effective strategies to enhance production in both regions.

RESEARCH METHODS

Data

This study requires input-output data for shallot production at the farm level in Indonesia. The available data so far is from the 2014 Agricultural Survey by the Central Statistics Agency (BPS). We are using data from 2,800 farm units on Java Island and 980 farm units Outside Java Island. The input-output data for shallot production used in this study represents the technology in the shallot production centers.

Analytical Methods

The main model required for this research is the shallot production function model. The production function is used to analyze production factors, technical efficiency and its determining factors. Technical efficiency is measured by comparing the production of each individual farm with the highest possible production in the industry in which the farms are located on given production technology (Farrel, 1957). The production frontier is represented by the production function estimated from this farm industry. The production function required is a production function that can describe the frontier production on a given technology. Two production functions are needed, in Java and outside of Java Island respectively. The assumption behind this is that the technology for shallot production on Java Island is different from that of outside Java islands.

Mathematically, technical efficiency is expressed as $lnY_i = lnY_i^* - u_i$, where Y_i is the observed shallot production, Y_i^* is frontier production ($-u_i$) is non-negative inefficiency ($u_i \geq 0$), and i is a number of farms in the industry. Production Y_i and Y_i^* are expressed in natural logarithm (ln) so that inefficiency can be expressed in the proportion or ratio exp($-u_i$) = Y_i/Y_i^*, it can also be expressed as a percentage. The inefficiency score, therefore, will range between 0 and 1. An inefficiency score equal to one means that the individual farm production is the same as the production of its frontier in the farm industry, which means the farm is efficient.

To get the inefficiency score as explained above, the production frontier lnY_i^* in $lnY_i = lnY_i^* - u_i$ will be estimated using the stochastic frontier production function $lnY_i^* = f(X;\beta) + v_i$, where X_i is the input vector or shallot production factors, and v_i is the noise following *iid* $N(0,\sigma^2)$. By including inefficiency ($-u_i$), the stochastic frontier production function becomes $lnY_i = f(X;\beta) + v_i - u_i$. It can also be presented as $lnY_i = f(X;\beta) + \epsilon_i$, where

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$\epsilon_i = v_i - u_i$. ϵ_i is the composed error term (Aigner *et al*. 1977, Kumbhakar *et al*. 2015, Coelli *et al*. 1998).

Operational Model

The operational model of the stochastic frontier production function in this study is expressed in the form of a Cobb-Douglas production function as follows:

$$lnY_i = \beta_0 + \beta_1 lnX_{1i} + \beta_2 lnX_{2i} + . . . + \beta_5 lnX_{5i} + \epsilon_i$$

Information:
Y : Production (Kg)
β_j : Parameter (j = 1,2, . . ., 5)
X_1 : Harvested area (M^2)
X_2 : Labor (Work Day)
X_3 : Seeds (Rp)
X_4 : Fertilizer (Rp)
X_5 : Pesticides (Rp)
ϵ_i : Composed Error term ($v_i - u_i$)
v_i : Noise
($-u_i$) : Inefficiency ($u_i \geq 0$)
Hypothetically $0 < \beta_j < 1$, for all j.

These production factors were chosen to estimate the production function in two regions (Java and outside Java) which are assumed to have different production technologies. These inputs include (1) planting area, representing land area, (2) seeds, (3) fertilizer, (4) pesticides, and (5) labor. These variables represent the main production factors in shallot production. Both production functions will be estimated using the same of input. The differences of shallot production function in Java and outside Java can be identified from the magnitude of elasticity and marginal product. From equation above, each parameter β_i is the production elasticity concerning the i_{th} factor. Mathematically the elasticity is obtained from the first derivative of equation.

$$\beta_j = \left(\frac{\partial Y_j}{\partial X_j}\right)\left(\frac{X_j}{Y}\right) = Elasticity$$

Elasticity (β_i) in equation above is defined as the percentage change in output caused by the percentage change in input. Very often the elasticity is interpreted as the magnitude of the production response to certain inputs. The greater β_j means more elastic of production and also means the production is more responsive to input. Furthermore, in this research, it is important to measure the marginal physical product (MPP) of input by using estimated elasticity. Rearranging equation, we get:

$$MPP_j = \left(\frac{\partial Y_j}{\partial X_j}\right) = \beta_j(Y/X_j)$$

Y/Xj is the average product estimated from the production function. MPP is the amount of

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additional output for each additional unit of input or can be interpreted as the contribution of each unit of input to output weighted by elasticity. The next analysis is to determine the factors that influence inefficiency using the model below.

$$u_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_4 Z_{4i} + v_i$$

Information:
u_i : Inefficiency
δ_k : Coefficient of Z_k (k=1,2,3,4)
Z_1 : Season (wet=1, dry=0)
Z_2 : Land type (wet=1, dry=0)
Z_3 : Farmer Group (yes=1, no=0)
Z_4 : Cooperative (yes=1, no=0)
v_i : Error

The expected coefficient values are δ_1, δ_2, δ_3, δ_4, <0 which means that they negatively affect inefficiency but positively affect efficiency. We hypothesize that the technical efficiency of shallot production in Java and outside Java is determined by exogenous factors, namely planting season, land type (irrigated and non-irrigated), and farmer membership in agricultural organizations such as farmer groups and cooperatives. These exogenous factors are expected to include differences in climatic conditions and available infrastructure in Java and outside Java.

RESULT AND DISCUSSION

Factors Affecting Shallot Production

The stochastic frontier production function in Java and outside Java Island estimated using the MLE method is presented in Table 2. In general, the production function meets the requirements of the Cobb-Douglas production function and can be used to measure production inefficiency. The two production functions have an Adjusted R-squared of 0.499 and 0.679 for Java and outside Java, respectively. The adjusted R-square of both production functions is small, which means there are still other factors that determine production but are not included. However, because the focus of this study is on the influence of production factors, the statistical indicator used is standard error. The table shows that all production factors that hypothetically determine shallot production are statistically significant, except for pesticides on outside Java's production function.

In Table 2, the results of the stochastic frontier production function using the ML method on Java and outside Java are presented. In general, the production function meets the properties of the Cobb-Douglas production function and this production function can be used to measure production inefficiency. Using OLS, we obtained an adjusted R-squared of 0.499 and 0.679 for Java and outside Java Island respectively. The adjusted R-square of both production functions is small, but since the focus of this study is on the influence of production factors, the statistical indicator used is the standard error of each variable. The table shows that all production factors of shallot production are statistically significant, except for pesticides outside Java Island.

Table 2. Maximum Likelihood Estimation of Cobb-Douglas Production Function of Shallot on

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Java Island and Outside Java Islands

Variable	Java Island				Outside Java Islands			
	Coefficient		Robust Std. Err	P>|z|	Coefficient		Robust Std. Err	P>|z|
Constant	0.5008	***	0.1247	0.000	-0.1326		0.1808	0.463
Harvested area (m^2)	0.3926	***	0.0324	0.000	0.3451	***	0.0453	0.000
Labor (Work Day)	0.1495	***	0.0241	0.000	0.2846	***	0.0389	0.000
Seeds (Rp)	0.2078	***	0.0299	0.000	0.2266	***	0.0422	0.000
Fertilizer (Rp)	0.2438	***	0.0230	0.000	0.2345	***	0.0314	0.000
Pesticide (Rp)	0.0372	**	0.0148	0.012	0.0089		0.0176	0.613
E (sigma u)	0.1215				15.7749			
Sigma v	0.5422		0.0158	0.000	0.4094		0.0143	0.000

Notes:
*** Significant at 1%)
**Significant at 5%

The main production factor to consider in addressing the dichotomy issue between Java Island and Outside Java Island is land, proxied by the harvested area of shallots. The production response (elasticity) of shallots to land in Java and Outside Java is higher compared to other production factors. This indicates that land has the highest contribution to shallot production, both in Java and outside Java. However, the production response of shallots to land in Java (0.3926) is almost the same as in Outside Java (0.3451). The indicator does not seem to support the issue of differences in land fertility between Java and outside Java. In practical terms, differences in land fertility are often measured by land productivity (output/land area). However, this measure does not take into account the contribution of other inputs, such as seeds and fertilizers. To calculate the true contribution of land to production, an appropriate measure is the marginal product of land. Because the elasticity of production concerning land is known and land productivity can be estimated, the marginal product of land can be calculated. Using the production function it is revealed that the marginal product of land are 4.69 tons and 2.00 tons for Java and outside Java, respectively. The marginal product of land which shows the contribution per unit of land (ceteris paribus) to total shallot production in the two regions is significantly different.

Table 2 shows that shallot production outside Java is slightly more responsive to seeds (0.2266) than that of in Java (0.2078). The difference in the contribution of seeds becomes a little more clearly expressed in the marginal product of seeds, where the marginal product of seeds outside Java (188.64 kg) is higher than the marginal product of seeds in Java (142.17 kg) for every additional unit (Rp 1,000) of seeds. Technically there are two types of seeds used in shallot production in Indonesia, namely tubers or shallot bulbs and shallot seeds. Shallot seeds are also called true shallot seeds (TSS). The quality of tubers is determined by the size of the tubers (Sumarni and Ahmad 2005). The TSS potentially has higher production compared to tuber seeds (Pangestuti and Sulistyaningsih 2011). Therefore, differences in shallot seeds' marginal product in Java and outside Java could be caused by variations in the type and quality of the seeds. Unfortunately, information on the use of seeds according to this type of shallot seeds is not available. The use of seeds, therefore, does not provide a strong argument for the dichotomy issue between Java and outside Java in shallot

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production.

The same explanation can be applied to fertilizers. In Table 2 it can be seen that the response of shallot production to fertilizers in Java (0.2438) is almost the same as outside Java (0.2345). However, further analysis shows that the marginal product of fertilizer in Java is much higher (826.81 kg) compared to outside Java (289.18 kg) for every additional unit (Rp 1,000) of fertilizer. This difference could be caused by the difference characteristics of agro-ecosystem in the two regions. The response of shallot production to the labor factor in Java is higher (0.1495) compared to outside Java (0.2846). The difference becomes more significant when measured by the marginal product of labor. The marginal product of labor in Java is 826.81 kg, much higher than outside Java (289.18 kg) for every additional labor (work day). The difference in the marginal product of labor in Java and outside Java could be caused by the quality of the labor such as age, education, and experience which will eventually differentiate their skills. The response of shallot production to pesticides outside Java is statistically insignificant. However, the marginal product of pesticides in Java (450.33 kg) is higher than outside Java (37.76 kg) for each additional unit (Rp 1,000) of pesticide. Differences in agro-ecosystem environments may cause differences in pest and disease intensity in the two regions.

Technical Efficiency of Shallot Production

The technical efficiency of shallot production in Java and outside Java is presented in Table 3. What is interesting is that the average technical efficiency score outside Java (0.97) is much higher than in Java (0.64). It has been mentioned above that technical efficiency is measured by comparing each observed production to each frontier that is most likely which is measured by the production frontier. Using Farrell's (1957) concept, the results indicate that the majority (97%) of a farm outside Java has approached their production frontier at the prevailing technology. On the other hand, in Java Island, only 64% of shallot farming produces close to their production frontiers. Table 3 also shows that the number of shallot farming with an efficiency score above 0.70 in Java is only 51.54%, significantly smaller compared to the same efficiency score outside of Java, which is 96.06%.

These findings must be interpreted carefully because as mentioned above, we applied two different production functions, which means that frontier production in Java and outside Java is based on different technologies. The differences in technology can be seen from the production per hectare (yield). It can be seen that the greater the efficiency score, the higher shallot productivity, both in Java and outside Java. The differences in technology can be seen from the production per hectare (yield). It can be seen that the greater the efficiency score, the higher shallot productivity, both in Java and outside Java. However, what is interesting to note is that farms that achieve maximum technical efficiency in Java have much higher productivity than outside Java. These findings imply that shallot production outside Java, with the existing technology, has largely reached their frontier. Increasing shallot production outside Java can only be achieved by improving or introducing new technology. On the other hand, in Java, the opportunity to increase production with the same technology is still available by 36%.

Table 3. Number of Farm Unit, Harvested Area, and Yield by Range of Technical Efficiency Score

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of Shallot Production in Java and Outside Java

Range of Efficiency Score	Java				Outside Java			
	Farm (Unit)	Percentage (%)	Harvested Area (Ha)	Yield (Ton/Ha)	Farm (Unit)	Percentage (%)	Harvested Area (Ha)	Yield (Ton/Ha)
<= 0.1	59	2.06	0.1721	0.46	1	0.11	0.2500	11.90
> 0.1 - 0.3	183	6.39	0.1821	1.68	0	0.00	-	-
> 0.3 - 0.5	336	11.73	0.1865	3.52	3	0.32	0.6167	1.30
> 0.5 - 0.7	784	27.37	0.2087	6.09	13	1.39	0.1538	3.59
> 0.7 - 0.9	1,476	51.54	0.2092	11.45	20	2.13	0.2575	6.30
> 0.9 - 1.0	26	0.91	0.1921	36.23	901	96.06	0.2168	6.58
Total	2864	100	0.2122	8.429	938	100	0.2181	6.52
Average Efficiency Score	0.64				0.97			

Factors Affecting Technical Inefficiency of Shallot Production

Increasing shallot production through improving technical efficiency can be achieved by knowing the determining factors. Table 4 presents the factors determining the technical efficiency of shallot production in Java and outside Java. The planting season significantly affects outside Java's technical efficiency, while it does not effect on Java. The wet seasons outside Java statistically significantly increase technical efficiency, but not in Java. This indicates that climatic conditions between the wet season and dry season outside Java could be significantly different. On the other hand, farmland in Java is relatively more fertile than outside Java, so the effect of seasonal differences on technical efficiency is not statistically significant.

Land type (wetland and dryland) statistically has a significant positive effect on technical efficiency. Wetland farming significantly increases technical efficiency, both in Java and outside Java. We know that the difference between wetlands and dry lands lies in the availability of water. We know that the difference between wetlands and dry lands lies in the availability of water. Land productivity or yield (tons/ha) of shallots is significantly influenced by water availability, both rainfall and irrigation (Palokitan et al. 2022). This research also confirms that the availability of irrigation infrastructure in Java and outside Java plays an important role in shallot production.

Table 4. Factors Affecting Technical Inefficiency of Shallot Farming in Java and Outside Java

Variable	Java Island				Outside Java Islands			
	Coefficient		Robust Std. Err	P>|z|	Coefficient		Robust Std. Err	P>|z|
Constant	5.9778	***	0.0558	0.000	-3.8541	***	0.5725	0.0000
Season (wet=1, dry=0)	0.0750		0.0475	0.115	-1.0724	*	0.6492	0.0990
Land type (wet=1, dry=0)	-0.4764	***	0.0546	0.000	-3.5234	***	0.5560	0.0000
Farmer Group (yes=1, no=0)	-0.2751	***	0.0547	0.000	-0.2372		0.6317	0.7070
Partnership (yes=1, no=0)	-0.1345		0.2033	0.508	-2.9807	**	1.3431	0.0260
Kooperative (yes=1, no=0)	-0.2951	**	0.1488	0.047	3.8566	***	0.7004	0.0000

Notes:
***Significant at 1%
**Significant at 5%
*Significant at 10%

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Farmer groups, partnerships and cooperatives in Java statistically have a positive effect on the technical efficiency of shallots. Compared to outside Java, farmer groups do not statistically significantly influence the technical efficiency of shallot production. Two other production organizations, partnerships and cooperatives, significantly influence the technical efficiency of shallot production. These findings indicate that agricultural organizations, both in Java and outside Java, have a positive contribution to the technical efficiency of shallot production. The contribution of these agricultural organizations to shallot production is to provide technical guidance on production. As a result, production technology applied by member farmers is relatively more unvaried and close to their frontier compared to non-member farmers.

CONCLUSION AND SUGGESTION

The production factors of land, labor, seeds, fertilizers and pesticides significantly determine shallot production in Java and outside Java. The significant differences in production in the two regions can be seen from the marginal product of these inputs rather than elasticities. Marginal products for land, labor, seeds, fertilizers and pesticides are higher in Java than outside Java. The marginal product of land, labor, seeds, fertilizers, and pesticides is higher in Java than outside Java, which means that land, labor, seeds, fertilizers, and pesticides would be more productive if they were used to produce shallots in Java instead of outside Java. The technical efficiency of shallot production outside Java is much higher than in Java. Since we applied two production functions, assuming two different production technologies, most shallot farming outside Java is close to their production frontier even though they are at a lower productivity level. On the other hand, only a small portion of shallot farming in Java is near their production frontier but with a higher level of productivity than outside Java. Technical factors, such as season and land type, as well as farmer organizations such as farmer groups, partnerships and cooperatives, contribute positively to the technical efficiency of shallot production, both in Java and outside Java. This research confirmed that the technical efficiency of shallot production is not only determined by technical aspects but also by institutional aspects that work in the environment where shallot farmings are located.

The development of shallots production outside Java requires improvements in production that enable to increase in the marginal productivity of inputs, such as seeds, fertilizers and pesticides. The main production factor that can leverage marginal products is true shallot seeds (TSS). The development of shallots outside Java must also be accompanied by increasing the availability of agricultural infrastructure, especially irrigation, and the development as well as arrangement of agricultural institutions such as farmer groups, cooperatives and partnerships between shallot farming and downstream industries.

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