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Technical Efficiency of Small-Scale Pig Farming in Indonesia

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Abstract

Live pigs are still the mainstay of livestock sub-sector exports in Indonesia. Although pig farming in Indonesia has competitiveness in the international market, its productivity shows a declining condition. The purpose of this research is to measure the level of technical efficiency of small-scale pig breeding and fattening businesses. The data used come from the results of the Farm Household Survey conducted by the Central Bureau of Statistics (BPS). The survey was conducted in 20 provinces in Indonesia, with a sample size of 6,681 small-scale or household-scale pig farming. The research used the Stochastic Production Frontier (SPF) model to measure the level of technical efficiency of pig farming and used the maximum likelihood method to estimate it. The results showed that the level of technical efficiency of pig farming is relatively low. The average technical efficiency level of fattening pig farming is higher than that of the breeding. The factors of farming experience, market orientation, and feed type combination have a positive influence in improving efficiency. Public policies that improve pig farmers' access to farm inputs and markets are expected to significantly improve the productivity of small-scale pig farming.

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INTRODUCTION

Pig farming in Indonesia has a comparative advantage reflected by a Domestic Resource Cost Ratio (DRCR) value smaller than one (Siregar & Ilham, 2016). Pork exports are still limited to live pigs, and based on data from Kementan (2020), are reportedly contributed almost 100% to the volume of livestock exports in 2019. However, the trend of pig exports tends to decline with an average growth from 2014-2019 of -0.68%. On the other hand, pork import data show a significantly increasing trend with an average growth from 2014-2019 of 53.5%.

Pork production in Indonesia according to Central Bureau of Statistics (BPS) data (2020) show an average production decline of -3.40% from 2014-2019. In addition, the growth of the pig population, which increases every year, is not accompanied by an increase in productivity and an increase in pork production. This indicates a problem with the productivity of the livestock business, which has not been able to produce maximum production from the inputs used. This is supported by research by Rahayu et al. (2020) which found that the productivity of pigs in urban Wamena is higher than in rural areas, based on the average value of litter size. This fact shows the need for evaluation to increase productivity in pig farming. Increased productivity can be achieved by increasing efficiency in using given technology, namely accelerating the managerial skills of farmers. This is in line with research by Rinaldi et al. (2019) stating that one of the priority strategies for pig farming development is to modernize farms to make them more efficient and productive. The development of farmer skills is particularly important because pig farming in developing countries, including Indonesia, is generally practiced by 80% smallholder farmers with less than 20 animals per farmer (Dietze, 2011).

Previous research on pig farming is generally based on case studies with a relatively limited number of samples and research locations (Aminu & Akhigbe-Ahonkhai, 2017; Raja et al., 2022; & Umeh et al., 2015). Previous studies related to efficiency improvement do not capture more farm-level managerial variables (Thanapongtharm et al., 2016). In contrast to previous studies, this research uses pig farm data at the farmer household level covering all provinces in Indonesia with a significant number of pig farm samples.

The novelty of this research lies in the adaptation of the production function that utilizes value-added as the dependent variable. In the conventional production function, the dependent variable is the quantity of output per period as applied in the research by Petrovska et al. (2013) & Umeh et al. (2015). The value-added approach is more appropriate than using the head unit of measurement because pigs sold to the market are not standardized among respondents in terms of weight or age, and it is possible that the value of by-products is included in the calculation of pig farm production.

The objectives of the study are (1) to identify the production factors of pig farming, (2) to measure and compare the level of technical efficiency of pig farming between those categorized as breeding pig farms and those categorized as fattening pig farms, and (3) to identify the factors that can affect the level of efficiency.

RESEARCH METHODS

The data used in this research are part of the Agricultural Census, namely the Farm Household Survey (ST2013-STU). The data collection period lasted from May 01, 2013 to April 30, 2014. This research covers household-scale pig farming across Indonesia using a sample of 20 provinces with a total of 6,681 respondents. The household business units selected for the samples are pig farmers who use pens as it allows for a more accurate calculation of the input and output relationship of pig farming.

This research uses the Maximum Likelihood Estimation (MLE) method with a one-step approach. The one-step approach is used to avoid the bias that arises from the two-step approach (Coelli et al., 2005). The MLE method in this research adopts the Stochastic Production Frontier (SPF) model which has been widely used in research related to pig farming, such as in Aminu & Akhigbe-Ahonkhai (2017) & Tian et al., (2015). As stated by Schmidt (2011), the one-step approach is to estimate the parameters of the model of factors affecting inefficiency simultaneously with the estimation of the parameters of the production function in the SPF model. Thus, the SPF model in this research consists of the Cobb-Douglas production function (equation 1a) and the technical inefficiency function (equation 1b) analyzed simultaneously with the STATA 2013 program. The basic SPF model is as follows:

$$\ln Y_i = \ln f\ (X_i\ ;\ \beta) + V_i - U_i \qquad (1)$$

Y_i indicates the real production for the individual i, and $f\ (X_i;\ \beta)$ refers to production potential (fully efficient); X_i are production inputs and other explanatory variables, and β is the corresponding unknown parameter; V_i is a random variable (can be positive or negative); dan U_i is a non-negative random variable that calculates the inefficiency.

Technical Efficiency

After conducting the SFA analysis, the value of technical efficiency (ET) can be obtained, which will answer the first research objective. Coelli et al. (2005) formulated ET as follows :

$$TE_i = \frac{Y_i}{Y_i^*} \qquad (2)$$

where, Y_i is the actual production, and $Y_i{}^*$ is the production frontier. Technical efficiency values range between zero and one. A higher technical efficiency value indicates a higher level of efficiency, relative to other observations in the sample.

Production Function

The production function is part of the SPF model to find the amount or measure of technical efficiency. The Cobb-Douglas production function is widely applied in agricultural research such as in Mwangi et al., (2020) & Tabe-Ojong & Molua (2017) because it has various advantages compared to other production function models. The specification of the SPF model used to estimate the production function parameters is formulated as follows:

$$\ln Y_{i(k)} = \ln \beta_{0(k)} + \beta_{1(k)} \ln X_{1i} + \beta_{2(k)} \ln X_{2i} + \beta_{3(k)} \ln X_{3i} + \beta_{4(k)} \ln X_{4i} + \beta_{5(k)} X_{5i} + v_{i(k)} - u_{i(k)} \quad (1a)$$

Remarks:

$Y_{i(k)}$ = production value of pig farming, i.e. accumulated value added of livestock and value of byproducts (Rp000/period)

X_1 = number of livestock cultivated (head/period)

X_2 = number of workers (people/period)

X_3 = amount of animal feed (kg/period)

X_4 = capital i.e. total cash costs-labor; feed; fuel, electricity, water; livestock health care; other expenses (Rp000/period)

X_5 = dummy livestock origin, where value 1=own production and value 0=from other sources

β_0 = intercept

Expected value of regression coefficient

$\beta_{1(k)}$ s.d. $\beta_{5(k)} > 0$.

$v_i - u_i$ = error term, where v_i is random error, and u_i is technical inefficiency effect in the model

i = the *i*-th livestock business household

k = the *k*-th livestock enterprise objective i.e. breeding and fattening and each is estimated separately

Technical Inefficiency Function

The technical inefficiency function of pig farming aims to answer the second objective of this research. The inefficiency effect is expressed as an explicit function of a vector of business-specific variables (Coelli et al., 2005). A negative coefficient of the inefficiency function parameter implies that the factor suppresses technical inefficiency in pig farming. The specification of the SPF model used to estimate the parameters of the inefficiency function is formulated as follows:

$$U_{i(k)} = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + \delta_8 Z_{8i} + \delta_9 Z_{9i} + \delta_{10} Z_{10i} + \delta_{11} Z_{11i} + \delta_{12} Z_{12i} + \delta_{13} Z_{13i} + \delta_{14} Z_{14i} \quad (1.b)$$

Remarks:

$U_{i(k)}$ = technical inefficiency value of the i-th farmer in farming destination group k

Z_1 = age of breeders (years)

Z_2 = number of family dependents (people)

Z_3 = formal education (years in school)

Z_4 = dummy sex (1=male, 0=female)

Z_5 = dummy farming experience (1= more than 10 years, 0=1 up to 10 years)

Z_6 = dummy of feedlot ownership (1=existing, 0=not)

Z_7 = dummy vaccination (1=yes, 0=no)

Z_8 = dummy combination of feed types (1=forage+factory feed+factory waste; 0=other)

Z_9 = dummy source of additional business capital (1=yes, 0=no)

Z_{10} = dummy outreach (1=yes, 0=no)

Z_{11} = dummy cooperative membership (1=yes, 0=no)

Z_{12} = dummy farmer group membership (1=yes, 0=no)

Z_{13} = dummy market orientation (1=yes, 0=no)

Z_{14} = dummy province (1=North Sumatra; NTT; Bali, 0=other)

The specifications of the two function models in SPF are then tested for feasibility through the Likelihood Ratio test or LR test (Kumbhakar et al., 2015). The model is said to be suitable for use if the LR test value is greater than the mixed Chi-square distribution (mixed X2) proposed by Kodde & Palm (1986) at a probability level of 1%.

RESULTS AND DISCUSSION

Technical Efficiency Measurement and Comparison

The estimation results in Table 1 show that all variables of production factors included in the SPF model are positive. This means that the addition of each production factor, namely livestock, workers, feed, capital, livestock origin, will increase the production value of pig farming. This result is in line with research by Aminu & Akhigbe-Ahonkhai (2017) & Tian et al. (2015), which show that the number of livestock, the amount of feed, capital, and workers have a positive effect on the production of pig farming.

Table 1. Estimation Results of Stochastic Production Function Frontier for Two Categories of Pig Farming in Indonesia

Variables	Breeding	Fattening
	Coefficient	Coefficient
Constant	6.387***	5.909***
Total livestock	0.437***	0.531***
	(1.54)	(1.79)
Workers	0.112***	0.019
	(1.07)	(1.08)
Feed	0.165***	0.178***
	(1.69)	(1.79)
Capital	0.129***	0.159***
	(1.59)	(1.51)
Origin of livestock	0.078**	0.011
	(1.04)	(1.04)
Sigma_u_sqr	0.382***	0.906***
Sigma_v_sqr	0.285	0.235
Log likelihood	-3,646.6707	-3,020.9387
Wald chi2(5)	3,607.01	6,106.04
Prob>chi2	0.0000	0.0000
LR test	492.335	562.044
Number of samples	3,542	3,139

Information: *** p<0.01; ** p<0.05; * p<0,1; VIF value in parentheses; all dummy variables use reference dummy = 0

Partial testing showed that all production factors significantly influenced the production value of breeding-type farming. However, in the fattening type of business, the variables of workers and origin of livestock were not statistically significant in influencing the value of livestock production. This may occur mainly because the length of maintenance in the fattening business type is relatively short. In addition, according to Umeh et al. (2015) the use of family workers can reduce production costs. Furthermore, the origin of livestock in the fattening type is also not significant. This is because most of the pigs (55%) are purchased from other farmers, not from their own production.

The results of the estimation of the technical efficiency of household-scale pig farming are summarized in Table 2. Table 2 shows the level of technical efficiency in the breeding and fattening pig business types, which have values of 55.9% and 63.6%, respectively. These results are different from the research by Latruffe et al., (2010) which found that the value of technical efficiency in breeding type farming was 55.3%

higher than the fattening type, which only reached 44.3%. The value of technical efficiency is relatively the same as the research result by Tian et al. (2015) in China. However, the value of technical efficiency is relatively low when compared to the results of research on pig farming in other countries, such as in Nigeria which amounted to 86% and even reached 97% (Aminu & Akhigbe-Ahonkhai, 2017; & Umeh et al., 2015), in India of 76% (Raja et al., 2022). Research by Weerasak et al. (2021) with DEA model shows the result of technical efficiency value reaching 89% with Variable Return to Scale approach and 43% with Constant Return to Scale approach.

The average value of technical efficiency obtained in this analysis clearly shows that the application of technology in small-scale pig farming in Indonesia is low and can still be improved by paying attention to its determinants.

Table 2: Distribution of Technical Efficiency Values of Two Categories of Pig Farming in Indonesia

Technical Efficiency	Breeding		Fattening	
	n	%	n	%
<0.5	1,265	35.71	652	20.77
0.5-0.6	691	19.51	406	12.93
0.6-0.7	757	21.37	655	20.87
0.7-0.8	589	16.63	873	27.81
0.8-0.9	238	6.72	545	17.36
0.9-1	2	0.06	8	0.25
Total samples	3.542	100	3,139	100
Average	0.559		0.636	
Std. Dev	0.172		0.179	
Min	0.056		0.039	
Max	0.919		0.931	

Factors Affecting Technical Inefficiency

The estimation results in Table 3 show the factors that are expected to affect the technical inefficiency of pig farming in Indonesia. In the breeding business type, the factors that significantly and hypothesized affect technical inefficiency are education, farming experience, feedlot ownership, vaccination, feed type combination, market orientation, and production province. Meanwhile, in the fattening business type, the factors that are expected to significantly and hypothesized to affect technical inefficiency include farming experience, vaccination, feed type combination, cooperatives, market orientation, and production province. The negative coefficient means that the higher the application of the factors used in the model by farmers, the smaller the technical inefficiency or the more efficient the pig farming business, and vice versa.

The role of education is proven to improve technical efficiency, and this is consistent with the results of the research by Tian et al. (2015). Education has an impact on farmers' ability to understand and respond positively to something new and increase innovation. Raja et al. (2022) confirm that the importance of education is primarily related to the ease of adopting management practices and innovations to increase production and profitability in farming. The farming experience factor was shown to improve technical efficiency in both breeding and fattening business types. This result is consistent with the findings of Aminu & Akhigbe-Ahonkhai (2017) & Umeh et al. (2015) that experience tends to increase the ability of farmers to obtain and process information about technology, which in turn increases efficiency.

Furthermore, feedlot ownership is also confirmed to increase technical efficiency, especially in the breeding business type. According to Tokach et al. (2016), this is a form of coordinated or integrated production by farmers as forage is one of the main components of animal feed. In terms of health, vaccination has been shown to improve technical efficiency in both types of business. Vaccination plays an important role in pig farming, especially because pigs are susceptible to disease.

Table 3. Technical Inefficiency Factors in Two Categories of Pig Farming in Indonesia

Variables	Breeding	Fattening
	Coefficient	Coefficient
Constant	1.164***	0.826**
Age	0.001	0.001
Family dependents	0.008	-0.048
Education	-0.011**	0.017
Sex	-0.017	-0.124
Farming experience	-0.250***	-0.336**
Feedlot ownership	-0.232***	0.722***
Vaccination	-0.458***	-0.647**
Feed type combination	-0.664**	-1.793**
Funding	0.002	-0.292
Outreach	0.008	0.296
Cooperatives	-0.028	-0.541**
Farmer Group	-0.068	-0.122
Market Orientation	-0.669***	-0.895***
Province	-0.555***	-1.597***
LR Test	401.491	374.225
Number of samples	3,542	3,139

Information: *** p<0.01; ** p<0.05; * p<0.1; all dummy variables use reference dummy = 0

The combination of feed types was also confirmed to improve technical efficiency in both types of business. The combination applied was generally local concentrate + factory concentrate + greenery. Local concentrates are generally obtained from factory waste such as tofu pulp, palm kernel meal, bran, and others. The combination meets the criteria for nutritional completeness in pigs. Research by Atsbeha et al. (2020) showed that the use of soybean meal in pig feed was proven to increase animal body weight and business profit.

The next factor is that farmer membership in cooperatives is also proven to increase technical efficiency, especially in the fattening business type. This finding is in line with research results from Olagunju et al. (2021) which states that cooperative membership supports the efficient use of resources, making members more productive than non-members.Farmers' market orientation is confirmed to improve technical efficiency which is confirmed as per the findings of Bahta et al. (2020). The more regularly farmers sell their products in the market, the more efficient their farming becomes. This factor can be an important concern for policy makers to be able to direct farmers to a business orientation. Furthermore, the results show that pig farming can be more efficient in the provinces of North Sumatra, NTT, and Bali than in other provinces. This result is in line with research by Kariyasa & Ilham (2003) which recommends that the development of pig farming should be directed to areas that meet three environmental conditions, namely from the social, cultural and religious aspects.

CONCLUSION

Small-scale or household-scale pig farming in Indonesia has a relatively low level of technical efficiency, respectively in the breeding business category and the fattening business category. With the current cultivation technology, small-scale pig farming still has the potential to increase productivity. Technical efficiency of household-scale pig farming is influenced by farmers' education and business experience, type and availability of feed and use of vaccination. Market orientation of the pig farming also has a positive influence on improving technical efficiency. The location of pig farming in North Sumatra, Bali and NTT significantly influences the improvement of technical efficiency levels.

RECOMMENDATION

The use of vaccines and the choice of feed combinations have a positive and significant impact on improving efficiency, so public policies are needed that allow pig farmers to gain better access to vaccines and the right feed. Public policies can also be done through pig farmers' easy access to markets as market orientation factors have a significant influence on improving technical efficiency. This research has the disadvantage of excluding household samples from the research due to various variables in the questionnaire categorized as no response. The exclusion of these samples may result in the emergence of bias towards the results of the measurement of technical efficiency. Future research will be more appropriate if it uses models and approaches that are able to minimize the bias caused by sample selection bias.

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