Comparative analysis of technical efficiency of piglet farming in three production center provinces in Indonesia

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ABSTRACT

Pork production occupies the third position in Indonesia, after chicken and beef. Even pigs occupy the top rank in contributing to Indonesia's live animal exports. The purpose of this study was to compare the level of technical efficiency of smallholder piglet production farming in three centers of pig production areas, namely North Sumatra, Bali, and East Nusa Tenggara (NTT). The research data was sourced from secondary data at the farm level, collected by the Central Statistics Agency of Indonesia, through the Livestock Business Household Survey. This research utilized the stochastic production frontier model to assess the production efficiency and the one-step maximum likelihood estimation (MLE) method to measure the level of technical efficiency and the significance of the factors. The results show that the average level of technical efficiency of piglet production farms in Indonesia is relatively low. Piglet production farms in Bali have the highest efficiency level and NTT is the lowest of the three provinces being compared. The number of pigs, feed expenditure, capital, and vaccinations are important factors in influencing production and the level of technical efficiency. Public policies that can increase farmers' access to production factors and better pig farm vaccine management become a necessity.

Keywords: Bali, Household survey, Stochastic production frontier, Vaccination

INTRODUCTION

The majority of Indonesia's population are adherents of Islam. For Muslims, pork and its various derivative products are forbidden for consumption. However, based on data from Livestock and Health Animal Statistics of Indonesia (LHASI) in 2020, it could be seen that pig farming is an important livestock business. Pork production occupies the third position after chicken and beef. The share of pork production was 5.2% of the total meat production in 2020 which is 4.6 million tons. Meanwhile, the share of chicken and beef at the same year were 79.3% and 11.0% respectively. National pork production is supported by the pig population which is

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increasing every year with a national average growth in 2014 to 2020 of 2.58%. The growth of Indonesia's pig population is higher than other countries such as China 1.70%, Vietnam -0.89%, or the Philippines -0.17% (Nga *et al.*, 2014). Pig farming is also the mainstay of Indonesia's livestock exports. Live animal exports were dominated by pigs, with a share of 99.1% of total live cattle exports in 2019. On the other hand, live animal imports were dominated by cattle, which amounted to 94.3% of total live animal imports.

Basically, the pig farming industry in Indonesia is centered in three regions, namely North Sumatra, Bali, and East Nusa Tenggara (NTT). Based on Livestock in Figures 2020 published by the Central Agency of Statistics of Indonesia (BPS), the three regions accounted for 66.2% of the total domestic pig production. The share of swine production in North Sumatra, Bali, and NTT were 16.7%, 30.0%, and 19.5%, respectively, of the total pig production in Indonesia, with the rest spread over 21 other regions (provinces).

Although pigs produce is the mainstay of livestock exports in Indonesia, the structure of pig agribusiness is still considered to be relatively unequal. The development of pig farming is not supported by developments in the downstream industry, especially livestock that specifically produces and provides piglets. Based on a household survey of livestock business in 2014 conducted by BPS, there are only 0.8% of pig farms that specialize in producing piglets. More than 52.8% of small-scale pig farmers use pig seeds that come from the piglets they raise, and not from purchases. In general, domestic pig farming businesses still have subsistence characteristics in the production factors they use (Keraru *et al.*, 2021). In the future it is necessary to have better quality pig breeds so that pig agribusiness in Indonesia will be more competitive. Therefore, it is necessary to study the efficiency level of the piglet industry on a smallholder farm scale. If the efficiency level is still low, then the performance can be improved by increasing the efficiency to get closer to the frontier. On the other hand, if the piglet industry is already efficient, it is necessary to has a techno-

logical breakthrough to improve the performance of the piglet industry at small holder farm scale.

Various studies on pig farms generally discuss the characteristics and performance of grower-finisher pig farming (Dedecker *et al.*, 2005; Galanopoulos *et al.*, 2006; Aminu and Akhigbe-Ahonkhai, 2017). Likewise, research that utilizes the stochastic production frontier model in assessing the performance of piglet production farms, has not been widely carried out (Sharma *et al.*, 1997; Lansink and Reinhard, 2004; Umeh *et al.*, 2015; Zhou *et al.*, 2015; Wang *et al.*, 2021). The objective of this study is to analyze and compare the level of technical efficiency of piglet production farms in three production centers in Indonesia, namely North Sumatra, Bali and NTT. As far as the best authors knowledge, no one has specifically discussed the level of technical efficiency of piglet production farms, namely farms that only raises breeding pigs to produce piglets, at the household level. Moreover, there has never been a comparison of the technical efficiency of pig farming in Bali, NTT, and North Sumatra. One of the main obstacles to assessing the technical efficiency of piglet production farms is the difficulty of obtaining sufficient research samples, especially cross section data that is suitable for analysis using the regression method. Less than 1 percent of the total smallholder pig farms in Indonesia that produce piglet are entirely dedicated to selling to the market. In the field, the characteristics of farms that produce piglet entirely sold to the market are also difficult to distinguish from those that produce piglets for their own use in the process of fattening pigs. The Livestock Census, which is the source of the data for this research, is an invaluable source of information to obtain an adequate number of observations for farms with a relatively small population in Indonesia. This research is based on the idea that piglet breeding is an important factor that determines the development of a pig farming business in an area. Thus, the knowledge of the technical efficiency of piglet breeding business is needed to be able to formulate appropriate public policies.

MATERIALS AND METHODS

Source of Data

The data used in this study is part of the latest Livestock Farms Household Survey (ST2013-STU). This study covers pig farms throughout Indonesia using samples from 20 provinces. The number of samples in the Livestock Business Household Survey is 6,738 pig farms on a household scale, and from the total number of samples there are only 57 farms who are categorized as piglet production nursery. The sample used in this study was dominated by piglet production farming from North Sumatra 28.01%; East Nusa Tenggara 27.86%; and Bali 21.42%. These three provinces have contributed more than 77% of the total sample. The household of piglet production farming selected as a sample must use a cage, because it allows a more accurate calculation of the relationship between input and output of pig farming.

Empirical Model and Method of Estimation

Research on the technical efficiency of farming using the stochastic production frontier (SPF) model has been widely carried out in various countries. The SPF model used is based on the thoughts of (Aigner *et al.*, 1977). The SPF estimation adopted is based on the ideas presented by (Jondrow *et al.*, 1982), namely through the variance decomposition model. In this study, inefficiency effect was formulated using the model suggested by (Battese and Coelli, 1995).

There are two production function models that are commonly used in stochastic production frontier research, namely the Cobb-Douglas model and the Translog model. Based on the results of a survey of several major SPF studies using SPF, the Cobb-Douglas production function model is the most widely used (Meeusen and van Den Broeck, 1977; Ahmad and Bravo-Ureta, 1996; Coelli and Battese, 1996; Tabe-Ojong and Molua, 2017; Mwangi *et al.*, 2020). In this study the Cobb-Douglas production function was deliberately chosen. There are two main reasons for using the Cobb-Douglas model in this study. First, the Cobb-Douglas production function requires a relatively small number of samples to obtain a degree of freedom equivalent to the Translog model. With the limited number of samples of piglet-producing farms obtained in the livestock national survey, which was only 57 samples, the Cobb-Douglas model became a more appropriate model. Second, the Translog model has a greater chance to violate the regression assumption, namely the existence of a high multicollinearity phenomenon among its independent variables, which is indicated by a high VIF value (Hair *et al.*, 2010).

The specification of Cobb-Douglas stochastic production frontier function employed in this study are as follow:

$$\ln Y_i = \ln \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 X_{5i} + v_i - u_i$$

Description:

$Y_i =$ the production value, namely the accumulation of livestock added value (IDR000)

$X_1 =$ quantity of pig cultivated (head)

$X_2 =$ quantity of labor (man days)

$X_3 =$ quantity of feed (kg)

$X_4 =$ capital, namely fuel, electricity, water; maintenance of livestock health; other expenses (IDR000)

$X_5 =$ *dummy* pig origin (=1 if own production, =0 if otherwise)

β_0 to $\beta_5 > 0 =$ coefficient of regression

$v_i - u_i =$ error term

Where, v_i is a random component which is assumed to be independently identically distributed (*iid*). u_i is a random variable that represents the effect of technical inefficiency in production. i is i^{th} household of piglet production farm. The efficiency effect (u_i) model used in this study employed the form function specification as suggested by Battese and Coelli (1995), which is

empirically expressed in the following equation:

$$u_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i}$$
$$+ \delta_6 Z_{6i} + \delta_7 Z_{7i} + \delta_8 Z_{8i} + \delta_9 Z_{9i}$$
$$+ \delta_{10} Z_{10i} + \delta_{11} Z_{11i}$$
$$+ \delta_{12} Z_{12i} + \delta_{13} Z_{13i}$$

Description:

u_i = the effect of technical inefficiency of ith piglet production farm

Z_1 = age of head of household (year)

Z_2 = number of household members (person)

Z_3 = formal education of household head (year)

Z_4 = *dummy* gender of household head (1=man, 0=otherwise)

Z_5 = *dummy* farming experience (1= more than 10 years, 0= otherwise)

Z_6 = *dummy* feed area (1= available, 0= otherwise)

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

Z_8 = *dummy* feed combination (1=forage+factory feed+industrial waste; 0=otherwise)

Z_9 = *dummy* access to finance (1=yes, 0=no)

Z_{10} = *dummy* access to extension (1=yes, 0=no)

Z_{11} = *dummy* member of cooperative (1=yes, 0=no)

Z_{12} = *dummy* market orientation (1=yes, 0=no)

Z_{13} = *dummy* province (1=North Sumatra, Bali; NTT, 0=otherwise)

Pig farmers produce piglets that were not standardized, and the production benefits received from the production process in on-farm were determined not only in units of tails or kilograms but also by looking at non-measurable quality of the piglets they produce. Therefore, the production function model used in this study did not use tails or kilograms but uses a value-added measure. If the units used are physical (tails or kilograms), then the model cannot capture the dimensions of quality in the product, so the results of production function became biased.

The value-added measure as a representation of output can capture the dimensions of quantity and quality of a product. Value added is also more suitable to represent output in farming where the harvest is not done at one time, such as harvesting corn or rice farming. Harvesting in piglets is not done at the same time but is harvested when the farmer needs cash or when it is deemed that the piglets are on time for sale. The stochastic production frontier function that did not use physical measurements for the relationship between output and input in pig farming had also been carried out by Etim *et al.* (2022) and Jabbar and Akter (2008). The stochastic frontier production function model does not have to be in the form of physical input-output relationship. It is possible that the input-output relationship represented by measurement of output and input in money value terms (Tenaye, 2020).

The estimation of the SPF model using the Cobb-Douglas production function above was carried out using the maximum likelihood estimation (MLE) approach without rejecting the assumption of heteroscedasticity, and the analysis was done with the help of the STATA 13 program (Wang and Schmidt, 2002; Belotti *et al.*, 2013; Tian *et al.*, 2015).

This study applied a single-stage MLE approach which it allows simultaneous estimation of the frontier production function and technical inefficiency model parameters and is free from high bias (Coelli *et al.*, 2005). The SPF model has been widely used in research related to pig farming as in Adetunji and Adeyemo (2012); Tian *et al.*(2015); and Aminu and Akhigbe-Ahonkhai (2017).

The SPF model specification test is carried

out by testing two hypotheses using the likelihood ratio (*LR*) test, as follows:

$$LR = -2[\ln\{L(H_0)\} / \ln\{L(H_1)\}]$$
$$= -2[\ln\{L(H_0)\} - ln\{L(H_1)\}]$$

The first hypothesis examines the existence of an inefficiency component of the total error term of the stochastic production function. In the first hypothesis test, $L(H_0)$ is the log likelihood value of the generalized linear model (GLM) and $L(H_1)$ is the log likelihood value of the Stochastic Frontier (SF). The second hypothesis tests that each explanatory variable in the inefficiency effect model has an influence on the level of inefficiency in the production process. In the second hypothesis test, $L(H_0)$ is the log likelihood value of the SF model without explanatory variables for the inefficiency effect model and $L(H_1)$ is the complete SF model with all explanatory variables for the inefficiency effect model. The calculated test statistic should be compared with the critical value of the mixed Chi-square distribution proposed by Kodde and Palm (1986). The null hypothesis is rejected if the *LR* test value is greater than the mixed Chi-square distribution at the 1% probability level.

RESULTS AND DISCUSSION

Performance of the Piglet Production Farming

Based on research samples, it can be said that piglet production is a small-scale farming business. The average number of pigs cultivated in one period is 15 pigs, consisting of 6 males and 9 females. Smallholder pig farming with the number of pigs below 50 heads is a business that is commonly found in many developing countries (Adetunji and Adeyemo, 2012; Thanapongtharm *et al.*, 2016). The average feed consumption per head per period is 343 kg. The composition of feed comes from various sources, namely factory waste (39%), forage (17%), factory feed (14%), agricultural waste (12%), household waste (6%), and others (12%).

Based on the composition of the feed sources, the piglet production farm relies on various types of waste as its feed source, which is 57%. In contrast, the content of feed from feed mills is only 12%. This can be an indication that the nature of subsistence in piglet farming is still relatively high, especially from the aspect of providing production inputs. Research Phengsavanh *et al.* (2010) in Northern Lao, Mekuriaw and Asmare (2014) in Northwestern Ethiopia, Leslie *et al.* (2015) in Indonesia, Nantima *et al.* (2015) along the Uganda-Kenya border, and Lekule and Kyvsgaard (2003) in resource-poor tropical areas of Africa, also found important sources of pig food originating from the surrounding environment and from agricultural and industrial waste or by-products. The amount of feed per head per period in Indonesia is relatively less than pig farm in other country, which daily feed intake ranging from 1.8 kg – 2.5 kg (Pierozan *et al.*, 2016). The optimum amount and

Table 1. Cost Structure and Profitability in Piglet Production Farming of the Three Provinces in Indonesia per Pig Head Managed per Period

Description	North Sumatra		Bali		NTT	
	IDR	%	IDR	%	IDR	%
A. Variable Cost	1,426.74		1,057.79		474.36	
Labor	560.57	38.55	250.72	21.95	179.49	33.81
Feed	796.49	54.77	760.44	66.58	232.73	43.84
Capital	69.68	4.79	46.63	4.08	62.15	11.71
B. Fixed Cost*	27.55	1.89	84.40	7.39	56.53	10.65
C. Total Cost (A+B)	1,454.29	100	1,142.19	100	530.89	100
D. Revenue (Value Added)	2,717.39	-	1,588.82	-	1,510.00	-
E. Profit (D-C)	1,263.10		446.63		979.11	

IDR in '000'. *With the following detail: fuel, electricity, water; maintenance of livestock health; other expenses. **With the following details: capital goods improvements; land lease; rent on stables, buildings, machinery, and tools; tax and levies; interest on loans.

composition of feed depends on the age, body weight, and breed of the pig, and the management of the pig's feed (Njoku *et al.*, 2013; Patience *et al.*, 2015; Colpoys *et al.*, 2016).

Based on research data, feed and labor were the dominant production factors in the cost structure of piglet farming (Table 1). Piglet farming in North Sumatra employed more feed and labor than farms in Bali and East Nusa Tenggara. The share of the use of inputs other than feed and labor, namely capital, was largest in piglet farming in East Nusa Tenggara. However, piglet farming in North Sumatra provided the highest added value and profit compared to piglet farming in the other two provinces.

Technical Efficiency of Piglet Production Farming

Based on the results of the likelihood ratio test on the SPF model used, it can be seen that there is an inefficiency effect in the model. This inefficiency effect is influenced by various factors, and this is also evident from the results of the likelihood ratio test obtained. Table 2 presents the results of the specification test on the Cobb-Douglas SPF model along with the factors that affect the inefficiency.

The estimation results of the SPF in Table 3 show that only labor inputs show no significant effect on production. By using primary data from a household-scale pig farming survey in Nigeria, the research of Umeh *et al.* (2015) found a positive effect of labor and feed on the level of production. However, the results of their research did not find a real effect of capital input on the level of production. On the other hand, this study found that capital has a significant positive effect on the level of piglet production farming.

In the SPF function to control the influence of seed sources, a dummy variable equal to 1 was included if the pigs that were cultivated come from own farming products and were equal to zero if others. The estimation results show that the origin of the pigs raised from the farm itself has a positive influence on the level of production. It seems that pigs that come from own live-

Table 2. Hypothesis Test for SPF Specification in Piglet Production Farming

Description	Results
No inefficiency effect; H_0: $\gamma = 0$	
LR Test	33.843
Mixed Chi-square	5.412
Decision	Reject H_0
Coefficient of inefficiency factors; H_0: $\delta_0 = \delta_1 = \delta_2 = \cdots \delta_n = 0$	
LR Test	29.266
Mixed Chi-square	28.485
Decision	Reject H_0

Table 3. The Estimation Result of SPF in Piglet Production Farming

Variable	Coefficient	Standard Error
Constant	6.269***	0.017
Total pig	0.360***	0.097
Labor	0.546[ns]	0.353
Feed	0.198***	0.022
Capital	0.137***	0.020
Pig's origin	0.797***	0.247
Sigma_u_sqr	0.489***	0.098
Sigma_v_sqr	0.000	0.000
Log likelihood	-43.9379	
Wald chi2(5)	3.30E+09	
Prob>chi2	0.0000	

*** $p<0.01$; ** $p<0.05$; * $p<0.1$; [ns] $p>0.1$

stock have better quality than pigs that come from other sources. Probably, breeders select the pigs it produces which were considered to have the best quality for the piglet production farm they are working on.

Based on the estimation results of the SPF model, the TE level of each observation can be measured. Of the 57 samples used in the SPF estimation, the average TE level of piglet production farms in Indonesia is 41.9% (Table 4), and can be categorized as a low level of TE, because it is below 70% (Coelli *et al.*, 2005). The efficiency level of piglet production farms is relatively lower when compared to pig farming in other countries (Tian *et al.*, 2015; Nguyen *et al.*, 2016). The estimation results from this study indicate that there is still great potential to increase the productivity of piglet production farms in Indonesia. The currently available pig farming technology does not appear to be optimally applied by breeders. It is still possible to improve the allocation of resource use in order to obtain a higher level of piglet production farm productivity. Increasing production through a new technology is certainly more difficult to do, because many factors can hinder the decision to adopt technology by piglet farmers (Zanu *et al.*,

2012).

If piglet production farms were grouped based on the area where the farm is located, it can be seen that piglet production farms in Bali have the highest average TE value and NTT is the lowest. Based on the research results presented in Table 5, the average TE values of piglet production farms in Bali and NTT are 50.1% and 35.9%, respectively. Bali also has the lowest diversity of TE values compared to the other two regions, with a coefficient of variation of 45.7%.

The TE value of piglet production farms in Bali relatively higher to the other two provinces was supported by Budaarsa's (2017) explanation that pig breeders in Bali have widely applied artificial insemination (AI). The positive effect of insemination methods and breeding practices for increasing pig farming productivity was also found by Galanopoulos *et al.* (2006) research in Greece.

Sources of Technical Inefficiency

The average value of technical efficiency in the three provinces which was classified as low, with available technology, indicates that there is a great opportunity to increase the productivity of piglet production farms. Table 6 presents the

Table 4. Distribution of TE Level in Piglet Production Farming

Technical Efficiency	Number of Observation	Percentage (%)
<0.5	37	64.91
0.5-0.6	7	12.28
0.6-0.7	4	7.02
0.7-0.8	2	3.51
0.8-0.9	2	3.51
0.9-1	5	8.77
Total sample	57	100
Mean	0.419	
Std. Dev	0.266	
Min	0.052	
Max	0.999	

Table 5. The Comparison of the Mean and Coefficient Variation of TE of Piglet Production Farming in Three Provinces

Province	Mean of TE	CV of TE
North Sumatera	0.437	0.645
Bali	0.501	0.457
NTT	0.359	0.618

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results of the estimation of factors that affect production inefficiency in piglet production farms. Table 6 should be presented as an integral part of Table 3, because it is generated by estimation using a one-step procedure with the maximum likelihood method, as suggested by Coelli *et al.* (2005). However, for the purposes of a clearer explanation followed, the results of processing the models of factors that affect technical inefficiency are separated into Table 6. Piglet production farms located in North Sumatra, Bali, and NTT are more efficient than in other provinces. This is indicated by the significant negative effect of the variable dummy of province on technical inefficiency.

Based on the estimation results, the age of the breeder has a negative effect on increasing technical efficiency. The older age of the head of the household has a negative and significant effect on the efficiency level of the piglet production farm. It seems that the younger generation is less and less interested in running a small-scale pig farming business, and prefers to work in the non-agricultural sector or work in urban areas.

The experience of raising pigs is a factor that can significantly affect the efficiency of a piglet production farm. Small-scale pig farms tend to use technology that has been traditionally passed down from generation to generation, so experience is a determining factor for success (Zanu *et al.*, 2012). This was reinforced by the estimation results which show the level of education and extension variables that do not have a significant effect. Likewise, the effect of the variable presence of feed land which significantly increases inefficiency can be an indication that piglet production farms that rely on feed sourced from nearby forages are lower in efficiency compare to farms that rely on feed from other feed sources.

The estimation results also show that vaccination, although with a low statistical significance level, does increase inefficiency. This is certainly contrary to expectations, where vaccination should be expected to improve the technical efficiency of piglet production farms. However, the estimation results that were contrary to this expectation could be an indication of the need to improve a more credible vaccination program in pig farms. Vaccinations that do not show the expected results may be caused by vaccination management or inadequate biosecurity practices at the internal pig farming level (Delsart *et al.*, 2020; Mutua and Dione, 2021). With the complexity of the problems surrounding pig farming, especially with the increasing ASF pandemic in pig farms, the role of research institutions and universities is urgently needed (Gunnarsson *et al.*, 2020) to improve the effectiveness of vaccination.

The model proposed in this study is able to capture the influence of institutions, namely co-

Table 6. The Sources of Technical Inefficiency in Piglet Production Farming in Indonesia

Variable	Coefficient	Standard Error
Constant	-0.241	0.755
Head of household age	0.038***	0.012
Number of household members	-0.032	0.079
Education of household head	0.010	0.023
Gender of household head	0.255	0.332
Farming experience	-0.936**	0.370
Feed area	0.816**	0.340
Vaccination	0.594*	0.338
Feed combination	-0.767	0.619
Access to financing	0.553	0.478
Access to extension	0.398	0.392
Member of cooperative	-0.662*	0.399
Market orientation	-0.323	0.333
Province	-0.754**	0.368

*** $p<0.01$; ** $p<0.05$; * $p<0.1$; ns $p>0.1$

operatives, in increasing the technical efficiency of piglet production farms. Farmer households who join cooperatives have a greater opportunity to gain access to the required input market and the output market for the piglets they produce. Members of agricultural cooperatives generally also have a higher level of technical efficiency when joining a cooperative (Ma *et al.*, 2018; Qu *et al.*, 2020; Olagunju *et al.*, 2021).

CONCLUSION

The results show that the efficiency level of piglet production farms in Indonesia is relatively low. The production factors of the number of livestock, feed expenditure, and capital has a positive and significant influence on the level of production. Bali has the highest level of technical efficiency and also the lowest level of variation in technical efficiency. The experience of raising pigs and the implementation of vaccination have contributed to the reduction of technical inefficiency in this farm. Public policy that can increase farmers' access to sows, feed and capital is expected to increase piglet production.

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