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Are There Differences in Technical, Allocative, and Cost Efficiencies Among Production Scales? The Case of Vietnamese Household Pig Production

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To enhance the competitiveness of smallholder pig production and reduce its influence on the environment in a sustainable way, scaling up production scale and adopting new management practices, called Vietnamese Good Husbandry Practices (VietGAHP), have been promoted as development strategies to smallholders in Vietnam in recent years. Although the advantage of economies of scale in production efficiency has been shed light on the commercial and large livestock farm in developed countries. However, a developing country such as Vietnam, smallholders are prominent and continue leading the agriculture, especially in pig production. The questions remain whether there is any chance to household pig production scale up their production and adopt new management practices to improve farm production efficiency. Thus, the objective of this study is to identify the influence of production scale and VietGAHP adoption to production efficiency of household pig production. Based on the high quality of primary data in our survey and a combination of an input–oriented data envelopment analysis, the Tobit model and other comprehensive statistical tests, the results found that the farmers could reduce 24.7% of their total costs without changing output level. Moreover, there were significantly higher allocative and cost efficiencies in larger production scale and adopting new management practices brought the higher level of technical efficiency. Based on these findings, we suggest ways that the government could improve the current system to help even among household pig production, who are the main agricultural producers in developing countries such as Vietnam, scale up their farms and adopt new management practices to improve their performance.

Key words: household pig production, production efficiency, production scale, VietGAHP, Vietnam

1 INTRODUCTION

Smallholders, or pig–farming households, commercial pig farms, and integrated commercial farms are the main pig producers in Vietnam. Pig production plays an important role in the Vietnamese meat supply, and smallholders are the main source, having supplied 3,733.3 thousand tons, accounting for 72.14% of the total live weight of livestock, in 2017 (GSOV, 2019a). Pig–farming households are those raising pig but whose annual revenue from pig farming is less than 1 billion dong (US$44,500). Although the Vietnamese government has a strategy to shift the pig industry from predominantly small–scale and household farms to large–scale and commercial farms, household pig production is currently the main source of pork in Vietnam (80%) (Lapar *et al.*, 2011) and is expected to retain this position until the 2030s (Lapar, 2014). According to the General Statistics Office of Vietnam, the total number of households raising pigs declined from around 4.1 million in 2011 to 3.44 million in 2016 (GSOV, 2018a). In term of structural changes, the percentage of households keeping 1–5 pigs decreased significantly (down 10%), from 77.55% in 2011 to 67.55% in 2016; however, the percentage of households with more than five pigs increased in 2016 compared to 2011, with the greatest increase found among households with 20–49 pigs (up 4.09%).

This structural change was supported by the Vietnamese government; however, the small–scale format still dominates (GSOV, 2018a). Further, the production efficiency of household pig production is low and the outcome unstable, owing to fluctuations in both production costs and product prices as well as disease outbreaks (GSOV, 2018a). To remain successful as pork suppliers in the Vietnamese pig industry, pig–raising households need to use their farm resources efficiently, especially with respect to reducing production costs.

Moreover, to contribute to enhance the competitiveness of household pig production and to protect the environment, Vietnamese Good Animal Husbandry Practice (VietGAHP), which is a type of Good Agricultural Practice for household pig production, was released and promoted by the Ministry of Agriculture and Rural Development (MARD) (MARD, 2011, 2016). Also, the adoption of VietGAHP has been supported by World Bank (World Bank, 2009).

Building on Farrell's (1957) definition and measurements of farm efficiency, there have been additional studies on livestock production incorporating measures of all components of efficiency (i.e., technical, allocative and cost efficiencies (Sharma *et al.*, 1999; Johansson, 2005; Hansson, 2008; Tonsor and Featherstone, 2009) or measuring single–efficiency (i.e., technical efficiency)

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(Jabbar and Akter, 2008; Ly *et al*., 2016; Tian *et al*., 2015).

Most existing studies have explored the various efficiency components in large and commercial farms; only Tian *et al*. (2015) and Ly *et al*. (2016) focused on smallholder farms. However, their studies focused only on a single efficiency: technical efficiency. Further, they did not find the exits of the relationship between farm size and technical efficiency. Moreover, current trends in Vietnamese pig–production industry notwithstanding, it is difficult to change immediately from a production characterized by small–scale farms to that of large–scale and commercial farms (Lapar, 2014; Tisdell, 2009). Thus, the question remains whether there is any advantage to having pig–farming households scale up their production to improve farm performance.

We could find no past studies that provided an analysis of the effect of production scale on all relevant efficiencies in the context of Vietnamese household pig farming. Therefore, this research sought to estimate the technical, allocative, and cost efficiencies in Vietnamese household pig production and the influence of production scale along with other factors on these efficiencies. This research provides empirical evidence that even among smallholders, the scale of production has greatly positive impacts on farms' performance in terms of improving allocative and cost efficiencies. Also, the adoption of the new agricultural management practice such as VietGAHP could bring the higher farm performance in term of technical efficiency. This result will be useful is establishing programs and policies to improve the performance of smallholders, currently the main agricultural producers, and sheds light on the future of East Asian small farming (Rigg *et al*., 2016), including in countries like Vietnam.

2 DATA AND METHODOLOGY

2.1 Study Site

The Hung Yen province of northern Vietnam benefits from its location in one of the two important deltas in the country, the Red River Delta; the delta features of a flat topography and plentiful fresh water are particularly well suited to farming. Thus, it is not surprising that as of 2016, agricultural areas comprised 58.1% (93 thousand hectares) of Hung Yen's total area and supplied 8.4% of the total 7.4 million pigs produced in the country (GSOV, 2018b). For these reasons, Hung Yen was chosen as the site of this study. The region has been continuously ranked as the top pig–producing region annually since 1995 and accounted for 25.4% of the total number of pigs in Vietnam in October 2018 (GSOV, 2019b). The production scale of this region has been changing: the total number of households raising fewer than 20 pigs declined from 803,902 in 2011 to 544,217 in 2016; during that same period, the number households raising 20–50 pigs increased from 56,097 to 89,913 and those raising 50 or more pigs increased from 10,505 to 30,920 (The state steering committee of the rural, agricultural and fishery census, 2017).

Among the province's 10 districts, Khoai–Chau and Tien–Lu and were purposely chosen for data collection because those two districts combined are expected to supply 30% and 30.6% of the total number of pigs produced in Hung Yen in 2020 and 2030, respectively (Hung Yen Department of Agriculture and Rural Development, 2017).

2.2 Data Collection

The data used in this studied were collected in April 2018 from a survey of pig–farming households in the Khoai–Chau and Tien–Lu districts of the Hung Yen province in Vietnam. A final sample of 230 pig–farming households that were producing and selling fattening pigs to the market as a final output were used in the analysis. All households were selected randomly from a list of households in five targeted communes in the third administrative tier of the Vietnamese administrative hierarchy at the district level; these targeted communes were chosen after consultation with the staff office of the Department of Agriculture and Rural Development for each district.

To explore the level of production efficiency by scale, this study divided the pig–farming production scale into three categories: small scale, which included all households raising fewer than 20 pigs; medium scale, which included all households raising 20–49 pigs, and large scale, which included all households raising 50 pigs or more. The distribution of sample size by production scale is shown in Table 1.

2.3 Empirical Model

2.3.1 Data Envelopment Analysis

Data envelopment analysis (DEA) is a well–known nonparametric method used widely in economics to measure production efficiency. Originally based on Farrell's (1957) definition of relative efficiency and used to measure firms' performance, DEA has the advantages of removing assumptions regarding the functional form of the frontier and the distributional form of the error term (Coelli, 1995). Most notably for our purposes, DEA can be used on data at the farm level without the likeli-

Table 1. Distribution of sample size (%)

District	Small scale (n = 78)	Medium scale (n = 112)	Large scale (n = 40)	Total (n = 230)
Tien–Lu	55.1	66.1	82.5	65.2
Khoai–Chau	44.9	33.9	17.5	34.8
Total	100.0	100.0	100.0	100.0

Source: Authors' survey in 2018; n = 230 hood of any significant influence caused by measurement error (e.g., missing variables, weather factors) (Coelli, 1995). Thus, we determined that DEA was an appropriate method to measure production efficiency and all its components—technical, allocative, and cost efficiencies—after examining other empirical studies on livestock production (e.g., Johansson, 2005; Sharma *et al.*, 1999). Hence, this study used DEA to estimate technical, allocative, and cost efficiencies in household pig production in Vietnam.

Technical Efficiency (TE). Input–oriented, TE is defined as the ability of a household to produce an unchanged level of output while using minimal inputs. To estimate TE, we used the input–oriented DEA model under variable returns to scale (VRS) (Banker *et al.*, 1984) as shown in Equation (1):

$$\begin{aligned} &\min_{\theta,\lambda}\theta, \\ &\text{Subject to} \\ &-y_i + Y\lambda \geq 0, \\ &\theta x_i - X\lambda \geq 0, \\ &N1'\lambda = 1 \\ &\lambda \geq 0 \end{aligned} \tag{1}$$

where x_i and y_i are the vectors of inputs and output of household i, respectively; i = 1, 2…N; X and Y are matrices of inputs and output of all households; N1 is an N* 1 vector of constants; and θ is the pure TE or TE_{vrs} is a scalar in [0, 1], indicating the TE of a household. If θ = 1, the household would be on the frontier and would thus be a technically efficient household; however, if θ < 1, the household would be technically inefficient. The linear programming problem had to be solved N times, once for each household in the sample to obtain a value of θ for each household.

Allocative efficiency (AE) and cost efficiency (CE). To estimate the CE and AE of pig production for a Vietnamese household, we solved the following cost–minimizing DEA model under the VRS assumption (Chavas & Aliber, 1993; Coelli *et al.*, 2002; Färe *et al.*, 1985; Ferrier & Lovell, 1990; Lovell, 1994), as shown in Equation (2):

$$\begin{aligned} &\min_{\lambda, x_i^*} w_i' x_i^*, \\ &\text{Subject to} \\ &-y_i + Y\lambda \geq 0, \\ &x_i^* - X\lambda \geq 0, \\ &N1'\lambda = 1 \\ &\lambda \geq 0 \end{aligned} \tag{2}$$

where w_i is a $N \times 1$ vector of input prices of household j; and x_i^* is the cost–minimum vector of input quantities for household i given the input prices w_i and the output levels y_i (which is calculated by the model), the CE of the i–th household can be measured as in Equation (3):

$$CE = w_i' x_i^* / w_i' x_i \tag{3}$$

is the ratio of minimum cost to observed cost for the i–th household. AE is the ability of a household to combine its inputs under optimal proportions, given the unchanged nature of their prices and the production technology (Farrell, 1957) and is calculated using Equation (4):

$$AE = CE / TE \tag{4}$$

Scale efficiency (SE). Scale efficiency means that a household must operate at a size that reaches a minimizing average cost; SE makes a comparison between a household's current operational size and what is most efficient in terms of minimizing average cost (Chavas & Aliber, 1993, Coelli *et al.*, 2005). Thus

$$SE = TE_{crs} / TE_{vrs} \tag{5}$$

in which, TE_{crs} is the overall TE that is reached when farmers operate at the optimal scale (Coelli *et al.*, 2002; Färe *et al.*, 1985), and it includes TE_{vrs} and SE (Färe *et al.*, 1985). TE_{crs} is obtained by deleting a constraint, N1' = 1 from Equation (1); Equation (6) was proposed by Charnes *et al.* (1978):

$$\begin{aligned} &\min_{\theta,\lambda}\theta, \\ &\text{Subject to} \\ &-y_i + Y\lambda \geq 0, \\ &\theta x_i - X\lambda \geq 0, \\ &\lambda \geq 0 \end{aligned} \tag{6}$$

in which the following are true: if SE = 1, then that is the optimal scale or CRS; if SE < 1, then the scale has inefficiency. However, when the SE does not reach the optimal scale, it will not show whether the household has increasing return to scale (IRS) or decreasing return to scale (DRS) (Coelli *et al.*, 2005). Thus, it requires an additional DEA model with non–increasing returns to scale (NIRS) by using N1'$\lambda \leq 1$ instead of N1'$\lambda = 1$ in Equation (1) (Coelli *et al.*, 2002, 2005) to estimate TE_{NIRS}, as shown in Equation (7):

$$\begin{aligned} &\min_{\theta,\lambda}\theta, \\ &\text{Subject to} \\ &-y_i + Y\lambda \geq 0, \\ &\theta x_i - X\lambda \geq 0, \\ &N1'\lambda \leq 1 \\ &\lambda \geq 0 \end{aligned} \tag{7}$$

If the TE_{NIRS} equals the TE_{vrs}, the household produces at the DRS. Inversely, if the TE_{NIRS} does not equal the TE_{vrs}, the household produces at the IRS.

Variables used in the DEA model. This study only focused on the efficiency analysis of pig–farming households that produced fattening pigs. Thus, the pig production had five inputs and one output. The output and inputs used in this study were based on the data of one cycle per household. The detailed definition and units of the output and inputs variables are: one *Output* (Y) is the total live weight of fattening pigs per household in one selling cycle (in tons); *Labor* (X_1) is the total amount of family labor used in one selling cycle per household (in person–days); *Feed* (X_2) is the total feedstuff expenses for one selling cycle per household (tons); *Breed* (X_3) is total number of piglets raised in one selling cycle per household (piglets by head count); *Other* variable inputs (X_4) is the total of all variable expenses, excluding labor, feed, and breed, such as electricity, breeding costs, and veterinary services in one selling cycle per household (in millions of dong); and *Fixed input* (X_5) is the depreciation of fixed assets (including buildings, tools, and sows) in one selling cycle per household (in millions of dong).

To solve the cost–minimizing DEA model to estimate CE, the prices of all five inputs we used are presented here: *Labor price* (W_1) was assumed to be zero per one person–day of family labor because the households (HHs) used only family labor; *Feed price* (W_2) is the price of feed per ton and equaled total feed expenses divided by X_2 (millions of dong/ton); and *Breed price* (W_3) is the price of breeding one piglet and equaled total breeding expenses divided by X_3 (millions of dong/piglets by head count). Because units of X_4 and X_5 are expressed in monetary terms, the calculation of the price of X_4 and X_5 was far from satisfactory. Following Ferrier and Lovell (1990) and other authors using the same DEA model to estimate TE, AE, and CE in agriculture fields (e.g., Chavas & Aliber, 1993; Coelli *et al.*, 2002; Dhungana *et al.*, 2004; Sharma *et al.*, 1999), we assumed the prices of X4 and X_5 to be the same and equal to one million dong for all households.

2.3.2 Tobit Model

Because of the bounded nature of the efficiencies (from 0% to 100%), the Tobit model has been widely adopted to regress factors on efficiency scores in the second stage of the DEA approach (Coelli *et al.*, 2002; Dhungana *et al.*, 2004; Johansson, 2005). We applied an empirical upper–limited Tobit model as shown in Equation (8):

$$y_i^* = \beta Z + u_i, \ with \ y_i = \begin{cases} y_i^* \ if \ y_i^* < 100 \\ 100 \ otherwise \end{cases} \qquad (8)$$

where y_i^* is the latent variable and an unobserved variable y_i, which is the efficiency score (three Tobit models with three observed dependent variables are TE, AE, and CE scores in percentages, respectively): Z is the vector of explained variables, including the characteristics of main pig producers in the households (Gender (1 = male, 0 = female), Education (years of formal schooling), Experience (years of experience in pig production), Training (1 = farmer trained in pig production technique, 0 otherwise)), VietGAHP adopter (1 = HH pig farm is registered as a member of VietGAHP group in the project of the Livestock Competitiveness and Food Safety supported by World Bank), Production scale as defined in 2.2 Data collection, No. pig raisers (family members joining in pig activity, R_Pig_ttincome (% of income from pig production in total income of household, Nonfarm income (1 = if household had income outside of agricultural activities, 0 otherwise), Total income (the total income household earned in 2017, included farm income and non farm income, measured in million dong), Credit access (1 = accessed credit for pig activity, 0 otherwise), Veterinary access (1 = accessed veterinary services, 0 otherwise); β are parameters; and u_i is a random error (we assumed that it followed a normal distribution in which the mean is 0 and variance is δ^2)

3 RESULTS AND DISCUSSION

3.1 Descriptive Statistics for Output, Inputs, and Characteristics of Vietnamese household pig production and their differences by Production Scale

The descriptive statistics for the output, input variables, and input prices are shown in Table 2. The results showed that, on average, each household raised around 17 pigs (by head count), requiring about 56 person–days and 4 tons of feed with other variable inputs (2.335 million dong) and fixed inputs (4.638 million dong) in one production cycle. The total output of one cycle was 1.741 tons per household. This means that the average live weight per fattening pig was 102.5 kg. Regarding the prices of feed and breed inputs, these varied substan-

Table 2. Descriptive statistics for output and input variables and input prices used in DEA model

Variable	Unit	Mean	Std. Dev.	Min.	Max.
Output (Y)	Ton/HH	1.741	1.017	0.360	7.200
Labor (X_1)	Person–days/HH	55.951	32.796	7.125	228.375
Feed (X_2)	Ton/HH	4.080	2.369	0.800	15.000
Breed (X_3)	heads	16.978	9.566	4.000	60.000
Other variable inputs (X_4)	Million dong/HH	2.335	2.262	0.165	17.500
Fixed input (X_5)	Million dong/HH	4.638	4.104	0.515	26.300
Labor price (W_1)	Thousand dong/person–day	0.000	0.000	0.000	0.000
Feed price (W_2)	Million dong/ton	9.885	0.912	6.345	13.755
Breed price (W_3)	Million dong/head	0.501	0.155	0.120	1.108
Price of other variable inputs (W_4)*	Million dong	1.000	0.000	1.000	1.000
Price of fixed input (W_5)*	Million dong	1.000	0.000	1.000	1.000

Source: Authors' survey in 2018; n = 230; Note: * According to Ferrier and Lovell (1990; Chavas and Aliber, 1993; Sharma *et al.*, 1999; Coelli *et al.*, 2002; Dhungana *et al.*, 2004), prices of X4 and X5 are assumed the same and equal to one million dong for all households.

tially among households. The mean feed price was 9.885 million dong per ton, with a range 6.345 to 13.755 million dong per ton; the mean of breed price was 0.501 million dong per piglet, with a range from 0.120 to 1.108 million dong.

There were differences in output, inputs, and some characteristics of pig–farm households by production scale (Table 3), with significant differences for output and feed input, breed input, other variable input, and fixed input. With respect to the farms' characteristics, we found statistically significant differences in the number of years of pig–farming experience, the number of family members involved in pig activity, the role of pig activity in terms of contributing to household income, total household income, and credit access for pig activity. Farmers in larger–scale operations had less experience in pig activity because the farmers running the bigger farms were generally younger than those running smaller farms. Other characteristics of larger farms: more family members were involved in pig activity; pig activity played a more important role in terms of contributing to household income; total incomes were higher; and they accessed credit services more often than the small farms did.

3.2 Level of Technical, Allocative, Cost, and Scale Efficiencies

Firstly, this research was interested in measuring each component of efficiency and scale efficiency. The frequency distribution of the technical, allocative, cost, and scale efficiencies of Vietnamese household pig–production subjects is shown in Table 4.

The mean of TE was 89.2%, with 44 households being fully efficient. This level of TE for the pig–farming households was significantly higher than what Sharma *et al*. (1999) found in for swine production in Hawaii (75.9%); what Tian *et al*. (2015) found for Chinese pig production (59.14%); or even what Jabbar and Akter (2008) found for pig production in northern Vietnam (73%). However, the level of TE found by this research is still reasonable when compared with the other research using the same methods to find TE means, such as Hansson's (2008) study of dairies in Sweden (87.7%); Lansink and Reinhard's (2004) study of pig farming in the Netherlands (89%); Wu and Prato's (2006) study of farms in Missouri (92%); and Ly *et al*. 's (2016) study of pig–farming households in Vietnam (85.4%). Variation can occur because the concept of efficiency is related to the frontier production based on the observed inputs and output data, and high levels in the TE score means are due to the homogeneity of the inputs and output data. This also occurred in our research because we focused on smallholders whose annual revenue from pigs was less than 1 billion dong (US$44,500). The high TE mean in our findings (89.2%) indicated that, on average, the pig–farming households in the Hung Yen province of

Table 3. Differences in output, inputs, and characteristics of Vietnamese household pig production by production scale

Variable	Small–scale (n = 78)		Medium–scale (n = 112)		Large–scale (n = 40)		Differences
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
Output	1.313	0.638	1.771	0.953	2.494	1.317	***
Inputs and inputs price							
Labor	56.504	32.404	55.197	33.844	56.986	31.289	
Feed	3.177	1.504	4.153	2.334	5.637	2.972	***
Breed	13.064	6.035	17.321	9.339	23.650	11.857	***
Other variable inputs	1.658	1.469	2.181	1.903	4.089	3.368	***
Fixed input	4.731	4.834	4.210	3.273	5.656	4.545	*
Feed price	9.883	1.082	9.834	0.859	10.034	0.665	
Breed price	486.506	174.036	505.451	144.874	514.075	146.586	
Pig–farm household characteristics							
Gender	0.620	0.490	0.720	0.449	0.750	0.439	
Education	8.205	2.182	8.143	2.035	8.725	2.783	
Experience	17.462	8.915	15.254	8.820	13.475	7.897	**
Training	0.870	0.336	0.800	0.399	0.900	0.304	
VietGAHP adopter	0.564	0.499	0.473	0.502	0.425	0.501	
No. pig raisers	0.860	0.350	0.800	0.322	0.950	0.221	*
R_Pig_ttincome	1.628	0.512	1.688	0.537	1.925	0.572	***
Nonfarm income	0.534	0.256	0.658	0.236	0.737	0.213	
Total income	0.740	0.439	0.710	0.458	0.700	0.464	***
Credit access	257.331	263.706	318.314	252.202	626.557	428.483	***
Veterinary access	0.360	0.483	0.480	0.502	0.760	0.423	

Source: Authors' survey in 2018; n = 230. Notes: ***, **, * = statistically significant at 1%, 5%, and 10% respectively; test of differences among group: Pearson's chi–squared test (Fisher's exact test) for dummy variable; Kruskal–Wallis test for measurement variable; US$1 = 22,454 dong)

Table 4. Frequency distributions of TE, AE, CE, and SE scores

Efficiency scores	TE		AE		CE		SE	
	No. of HH	% of HH	No. of HH	% of HH	No. of HH	% of HH	No. of HH	% of HH
< 70%	1	0.4	9	3.9	69	30	0	0
70–80%	25	10.9	57	24.8	97	42.2	3	1.3
80–90%	105	45.7	99	43	42	18.3	21	9.1
90–100%	55	23.9	59	25.7	16	7	177	77
100%	44	19.1	6	2.6	6	2.6	29	12.6
Mean (%)	89.2		84.6		75.3		95.8	
Std. Dev. (%)	7.8		9.3		10.2		4.8	
Min. (%)	66.1		52.3		46.6		73.4	
Max. (%)	100		100		100		100	

Source: Authors' survey in 2018; n = 230; HH = household

northern Vietnam that we studied could save 10.8% of their physical inputs to produce the same level of output.

Secondly, the mean of AE was 84.6%, with only six fully efficient households. This result suggested a second way that these pig farming households could produce the same level of output but with costs reduced by 15.4%: by combining input quantities based on their relative input prices. When we combined the TE and AE into CE, the mean CE score was 75.3%, with six fully efficient households. This means that, on average, households could reduce total costs by 24.7% without any change to output levels. A cost inefficiency was contributed by allocative inefficiency and technical inefficiency, respectively. The same result was found by Hansson (2008) and Johansson (2005) for Swedish dairy farms and Wu and Prato (2006) for Missouri farms. The similarities may be because both these studies and our study focused on exploiting the advantage of cost efficiency to increase economic efficiency while the mean of TE was high; therefore, the cost efficiency was much more dependent on AE than on TE.

Table 4 shows that the percentage of pig–farming households with a level of efficiency of less than 70% was 30% for CE, 0.40% for TE, and 3.9% for AE. This suggests that there is still significant potential for increasing economic efficiency, in terms of improving cost efficiency, for these pig–farming households in Vietnam.

Another interesting result was that the mean of SE was 95.8%, with the variation ranging from 73.4% to 100% (Table 4) and 12.61% of pig–farming households reaching the optimal scale (Table 5). This result indicated that pig–farming households were close to their optimal scale with their current resources in Vietnam, but 70% of them still produced under IRS. This means that they still had to make changes to improve their efficiency—specifically, increasing their production scale. This result was in line with the findings of Hansson (2008) for Swedish dairy farms. Moreover, a Pearson's Chi–squared test proved that the number of households producing at IRS decreased for large–scale production, confirming that increasing production scale enhanced overall efficiency—the combination of scale, technical, and allocative efficiencies.

3.3 Influence of Production Scale and Other Factors on Technical, Allocative, and Cost Efficiencies

The second objective of this study was to identify the influence of various factors on technical, allocative, and cost efficiencies, especially the influence of production scale. The sign of the coefficients of the Tobit model explained a relationship between the explanatory variables and efficiency scores (Gujarati, 2011). As mentioned above, the inefficiency of CE was caused more by AE inefficiency than by TE inefficiency, and the mean of TE was high. We combined the results of the Tobit model with those of three statistical tests (i.e., Spearman's correlation, analysis of variance, and the Kruskal–Wallis test) to measure the influence of production of scale on the efficiency scores. The influence of

Table 5. Distribution of scale efficiency of pig–farming households by production scale (% of households)

IRS	Small	Medium	Large	Total
CRS	10.26	14.29	12.50	12.61
DRS	8.97	18.75	30.00	17.39
IRS	80.77	66.96	57.50	70.00
Total	100.00	100.00	100.00	100.00

Source: Authors' survey in 2018. Pearson's chi–square (4) = 9.878**. Note: ** is statistically significant level at 5%; CRS: constant return to scale; DRS decreasing to scale and IRS: Increasing return to scale production scale on allocative and cost efficiencies was consistent. Thus, the following paragraphs focus on the effect of production scale and other factors on the level efficiency of AE and CE to improve efficiency levels in household pig farming.

Firstly, the scale of production, training, and access to veterinary services were found to have positively significant impacts on AE (Table 6), especially the coefficients of production scales were statistically significant at least 5%. Households producing on a large scale had significant AE scores higher than households producing on a small scale. The same finding was found by Wu and Prato (2006). This means that large farms had a better combination of inputs based on their prices compared to small farms. This relationship was also true when comparing medium– and small–size farms. Thus, even among smallholders, the advantage of economics of scale is still effective.

Training and access to veterinary services were supplied free to pig farmers by the Vietnamese government; the results confirm the positive effect of the government's investment. One notable finding was that access to credit services had a negative influence on AE. All the households in this study that had accessed credit services had done so freely through the market, without any special support from the government to remain in business. The cost of credit services contributed significantly to the total cost of pig production of the households.

With respect to CE, larger farms, nonfarm income, and experience were all have found to have positive impacts, while access to credit had a negative impact, as with AE (Table 6). Large and medium farms had better CEs compared to small farms (Table 6). This contrasts with the findings of Tonsor and Featherstone (2009) who found that the larger number of pig heads in feeder–to–finish farm type was less cost efficient. These authors supposed that feeder–to–finish farm type was new specialized farm type and was developed too large. Thus, a management of these farms was on the way of a learning new technology. However, in our study, household pig production is a traditional and predominant farm type. Thus, household pig farm is not on a learning process of a new management technology, they could get the advantage of economics of scale to get higher level of CE.

As expectedly, nonfarm income increased CE, especially the price of pork in the market decreased significantly and continuously from January 2017 into the study period, April 2018 (Dan, 2018; Hien, 2017); to survive and sustain their pig–production operations, household pig farmers added other non–agricultural sources of income.

In summary, the trends observed in the large farms showed that production scale had the impact on AE and CE: larger production led to great efficiency. The relationship between production scale and these scores is revealed by their Spearman's correlations, shown in Table 7; there were weak positive correlations between AE, CE, and scale, and these were statistically significant at 5% with Spearman's coefficients (0.146 and 0.165, respectively) (Table 7). The results of the analysis of variance and Kruskal–Wallis tests showed that there were significant differences in the means of AE and CE by production scale (Table 8). This means that large farms had greater allocative and cost efficiency than

Table 6. Factors' influences on technical, allocative, and cost efficiencies in Vietnamese household pig production

Variable	TE		AE		CE	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Gender	1.142	1.395	1.094	1.346	2.134	1.462
Education	–0.076	0.283	0.373	0.273	0.360	0.297
Experience	0.169 **	0.073	0.078	0.070	0.179 **	0.076
Training	–3.195 *	1.809	3.214 *	1.723	0.943	1.872
VietGAHP adopter	2.277 *	1.360	0.074	1.309	1.676	1.421
Scale						
Medium	2.565 *	1.411	2.438 **	1.165	4.543 ***	1.486
Large	2.420	2.199	5.812 ***	2.791	8.858 ***	2.307
No. pig raisers	–0.018	1.212	0.259	1.377	0.260	1.265
R_Pig_ttincome	–2.984	1.314	2.310	0.002	–0.223	3.032
Nonfarm income	2.405 *	2.725	2.117	1.260	3.619 **	1.494
Total income	0.004 *		–0.004 **	1.264	–0.001	0.002
Credit access	–1.947	1.317	–3.682 ***	4.120	–4.735 ***	1.368
Veterinary access	–2.053	4.266	2.451 *	0.410	1.043	1.373
Constant	88.253 ***	0.481	72.027 ***	1.165	61.940 ***	4.471
Sigma	8.738	1.981	8.615	2.791	9.359	0.446
LR chi–squared (13)	27.98 **		41.99 ***		47.40 ***	
Log–likelihood	–713.598		–807.911		–827.819	

Source: Authors' survey, 2018; n = 230. Notes: ***, **, and * = statistically significant at level 1%, 5%, and 10%, respectively

Table 7. Impact of production scale on TE, AE, and CE

Efficiency	Spearman's coefficient
TE	0.033
AE	0.146**
CE	0.165**

Source: Authors' survey, 2018; n = 230. Notes: ** = statistically significant at level 5%

Table 8. Statistical test of impact of production scale on the mean of TE, AE, and CE

Scale	TE (%)	AE (%)	CE (%)
Small scale	88.12	82.87	72.81
Medium scale	89.79	84.74	76.00
Large scale	89.45	87.52	78.42
Analysis of variance	1.08	3.43 **	4.63**
Kruskal–Wallis test	1.47	5.01*	6.61**

Source: Authors' survey, 2018; n = 230. Notes: **, and * = statistically significant at level 5%, and 10%, respectively

small farms did, confirming that increasing the scale of production improved the chances of achieving higher allocative and cost efficiency scores for Vietnamese household pig farms.

4 CONCLUSIONS AND POLICY IMPLICATIONS

In keeping with the Vietnamese government's policy of supporting an expansion in pig–production scales, household–based pig production has been changing, with an increasing number of small farms scaling up to become large–scale operations. The country is increasingly trending toward the consolidation of diverse smallholder farms into larger, pig–specializing farms (Tisdell, 2009). However, the rate of change is slow, and smallholder pig–farm households are still the main pork suppliers in Vietnam (GSOV, 2018a). The households studied lacked the resources to become large commercial farms; therefore, to remain competitive, it was imperative that they produce with maximum efficiency, changing their production scale to the extent possible to keep up with the market competition. The objective of the study was to measure the technical, allocative, and cost efficiencies and the influence of production scale, along with other factors, on these efficiencies in Vietnamese household pig production.

First, we found high efficiency scores among the Vietnamese pig–farming households: TE 89.2%, AE 84.6%, CE 75.3%, and SE 95.4%. However, the households still could reduce their total costs by 24.7% with no decrease in output. Their inefficiency of cost was caused by their allocative and technical inefficiency. Although the pig–farming households nearly reached their optimal production scale, 70% of them were still producing on too small a scale, and they could enhance their SE by producing at their optimal production scale.

Second, we used a combination of the results of the Tobit model and of three tests (Spearman's correlation, analysis of variance, and the Kruskal–Wallis test), and found production scale to exert a positive influence on allocative and cost efficiencies for these Vietnamese household pig farms. However, the influence of production scale on TE could not be confirmed because the results of the Tobit model showed that medium– and large–scale operations could lead to higher levels of TE, while the other three tests did not provide evidence of a relationship between TE and production scale. Hence, one possible implication was that scaling up household pig farms could enhance their production efficiency by taking advantage of allocative and cost efficiencies. Thus, to improve allocative and cost efficiency, the government should continue to deliver training and access to veterinary services to small–hold farmers. Additionally, the government should reduce the negative impact of the cost of credit by giving the farmers favorable credit conditions, such as longer borrowing periods, lower interest rates, or both, comparable to the credit services available in the market. Furthermore, the government should encourage less experienced farmers or young farmers who tend to scale up their farms to reduce their vulnerability through special training programs such as learning trips and consultations with high– efficiency farmers. Last, the adoption of VietGAHP brought the higher level of TE but the influence of production scale on TE was not clear. Thus, further study is required to more clearly elucidate the relationship between production scale and the level of TE among smallholders in pig production.

AUTHOR CONTRIBUTIONS

All listed authors have contributed in this manuscript. Nguyen Thi Ly carried out the study's conception and design, collected data, analyzed data and drafted the manuscript. Teruaki Nanseki contributed to develop the study's conception and research flamework design, advised the data interpretation, made critical revision of the manuscript. He was also responsible for the oversight of the research activity planning and execution and is responsible for ensuring that the descriptions are accurate and agreed by all authors. Yosuke Chomei assisted the study's conception and design, advised the data interpretation and revised the manuscript. All authors have read and approved the final manuscript entitled "Are There Differences in Technical, Allocative, and Cost Efficiencies among Production Scales? The Case of Vietnamese Household Pig Production".

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