Technical Efficiency and Its Determinants in Household Pig Production in Vietnam: A DEA Approach

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Using a two-stage approach with an input-oriented DEA model, this study investigates technical efficiency in household pig production in Vietnam and seeks to determine which factors affect it. The results show that overall technical efficiency (TEcrs) was 80.40%. It is further found that households' poor management, rather than their operating scales, prevented technical efficiency from reaching its full potential. Factors affecting on TEcrs include live weight per fattening pig, breeding time, experience, education, family member joining in pig production, income from pig, access to credit and veterinary services. Thus, potential means of improving technical efficiency in pig production are suggested and thereby enhancing Vietnamese households' performance.

Key words: Technical efficiency, pig production, two-stage DEA model

1. Introduction

In Vietnam, pig production is not only one of the main agricultural sectors but also a major source of income and central household activity in rural areas. According to the General Statistics Office of Vietnam (GSO) (GSO, 2013), the value of livestock constitutes 26.8% of the gross agricultural output, a ratio that has been growing overtime. It is predicted that by 2020, livestock production, of which pig production is the greatest component, will constitute over 42% of agricultural output. It is further thought that pig production will come to supply 63% of the country's total meat production by that same time (Vietnamese Prime Minister, 2008). Pig production is almost entirely conducted by small farmers, who own approximately 80% of all pigs (AGAL, 2005). Epprecht (2005) argues that the pig sector is one of the most important contributors to household income within the livestock sector. However, household pig production is reliant on the family's own resources, such as labor, land, and feed produced from agricultural products. In addition, the Vietnamese government's strategy for the future of the pig sector through 2020 holds that production should be shifted from small-scale and family operations to large, intensive and commercial scale operations (Vietnamese Prime Minister, 2008). Thus, household pig production will face increased threats, though it is still believed that it will continue to dominate Vietnam's pork

industry (Tisdell, 2010). Furthermore, it is also believed that household pig producers have a comparative advantage within the pig industry (Lapar et al., 2012).

Thus, if households want pig production to continue contributing to their income and to continue supplying pork, they must utilize their resources more efficiently. This study focuses on farrow-to-finish household pig producers who account for 55.85% of Vietnam's pig farmers (Tung, 2009). Farrow-to-finish is a full cycle of pig production process that keeps breeding sows and producing piglets that are grown and fattened until they can be sold for their meat (Lapar et al., 2012). Furthermore, in order to create jobs and income, household farrow-to-finish pig producers increase the scale of their operation and utilize husbandry techniques, such as cross breeding and artificial insemination, in order to improve their performance. However, they still face numerous challenges, such as limited resources, diseases, a lack of political support, and poor husbandry techniques. As such, the technical efficiency in farrow-to-finish pig production varies based on both time and the farmer in question.

Based on Farrell (1957) seminal article, technical efficiency is defined as "the ability of a farm to use minimum level of inputs given the same output." Recently, several studies have used Data Envelopment Analysis (DEA) approaches to study productive efficiency in pig farming; however, most of these ignored small-scale household operations in developing countries, where pig

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production is integral to both the agricultural sector and to households. To our knowledge, only Muger & Featherstone (2008) investigated technical efficiency and its determinants in backyard pig production, with their focus being limited to the Philippines. Thus, this study will estimate the level of technical efficiency and its determinants in farrow-to-finish pig production in Vietnamese households.

2. Methodology

1) Study sites and data collection

Hung Yen is an agricultural province in the Red River Delta, which is in northern Vietnam. According to the Hung Yen Department of Agricultural and Rural Development (2010) about 90% of people living in rural areas work in the agricultural sector. In Hung Yen in 2009, livestock accounted for 45.5% of total gross agricultural production and is predicted to reach 50.1% in 2015, with 80% of that coming from pig production. Hung Yen, along with the rest of the Red River area, has a high density population and a decreasing quantity of farm land. In this area, pig production continues to be households' main activity and source of income. The field survey was conducted in 3 communes of the Tien Lu district.

Primary data was gathered between August and September, 2014. A total of 177 farrow-to-finish pig producing households were randomly selected to complete structured and semi-structured questionnaires, but only 161 were used in the analysis.

2) Data analysis

To accomplish the research objectives, two-stage DEA approach will be used in this paper as suggested by Coelli et al. (2005), the DEA model should calculate the efficiency of each household in the first step, and in the second step, a Tobit model should be used to determine the effect of each factor on the efficiency score.

DEA models are linear programming methods that can be used to calculate the frontier production function of a set of households and evaluate their relative technical efficiency. In this study, two input-oriented models with two assumptions will be used to study the efficiency of households' resource allocations. The first assumption is that there are constant returns to scale (CRS). This assumption allows us to estimate the technical efficiency associated with constant return to scale or the overall technical efficiency (TEcrs) (Charnes et al., 1978) by

solving the following linear program:

$$\begin{aligned} & \min_{\theta, \lambda} \theta, \\ & s. t. -q_i + Q\lambda \geq 0, \theta x_i - X\lambda \geq 0, \lambda \geq 0, \end{aligned} \quad (1)$$

where x_i and q_i are the vectors of inputs and outputs for decision making unit i (DMU _{i}), respectively ($i=1, 2, \dots, I$); X and Q are matrices of inputs and outputs for all DMU; λ is an $I \times 1$ vector of constants; and θ is a scalar in $[0,1]$ that identifies the technical efficiency scores of each DMU. It means that $\theta = 1$ indicates a technical efficiency; $\theta < 1$ indicates a technical inefficiency. The second assumption is that there are variable returns to scale, which allows us to estimate technical efficiency under variable returns to scale or pure technical efficiency (TEvrs) (Banker et al., 1984). We are able to apply this assumption by reformulating Eq. (1) with a convexity constraint, $1'\lambda = 1$; consequently, we obtain Eq. (2), in which $1'$ is an $I \times 1$ vector of ones.

$$\begin{aligned} & \min_{\theta, \lambda} \theta, \\ & s. t. -q_i + Q\lambda \geq 0, \theta x_i - X\lambda \geq 0, 1'\lambda = 1, \lambda \geq 0 \end{aligned} \quad (2)$$

If there is a difference in TEcrs and TEvrs scores for a particular firm, scale efficiency (SE) can be calculated as follows:

$$SE = TE_{crs} / TE_{vrs} \quad (3)$$

If $SE = 1$, then the firm enjoys CRS. If $SE < 1$, then the firm has scale inefficiency.

The DEA model employed in this study includes one output and four inputs: Output (y) is the total live weight of fattened pigs produced (in kg). The four inputs include labor (the total amount of family and hired labor, in man-days); feed (the total value of feedstuff, in 1000 VND¹); other variable costs (the total of all variable expenses excluding labor and feed, such as electricity and veterinary service, in 1000 VND); and the fixed cost (the depreciation of fixed assets (such as buildings and machinery), in 1000 VND). The output and all of inputs in the first stage should be normalized by the number of sows per cycle to increase the variation of the selected variables and to identify whether pig farms have an optimal size related to the number of sows as Galanopoulos et al. (2006).

The DEA efficiency scores range from zero to one, and as such, a Tobit model is often used to explain the differences in scores based on given explanatory variables. However, the technical efficiency score is never equal zero; thus, this study uses a Tobit model with an upper limit of one, as prescribed by Muger & Featherstone (2008). Two Tobit models are used with the dependent variables being TEvrs and SE. Thus, the empirical Tobit models may be defined as:

¹ The exchange rate in 2012 was 1USD = 20,820 VND

$$y_i^* = Z\beta + u_i \quad (4)$$

with the observed, dependent variable y given, by

$$y_i = \begin{cases} y_i^* & \text{if } y_i^* < 1 \\ 1 & \text{if otherwise} \end{cases} \quad (5)$$

where: y_i^* is the latent variable; Z represents the vector of explanatory variables, including various farmer and household characteristics; β represents the estimated parameters; and u_i is a random error term, which is assumed to be normally distributed with a mean of zero and variance of σ^2 .

3. Results and discussion

1) Descriptive statistics of households' socio-economic characteristics

Table 1 presents the descriptive statistics for the inputs and output in the farrow-to-finish pig production function.

Table 1. Descriptive statistics for the DEA model's inputs and output

Variables	Unit	Mean	St. dev	Min	Max
Inputs					
Labor	man-day/sow	27.83	12.56	9.60	71.88
Feed	1000 VND/sow	29021.67	6926.11	13823.00	46793.25
Other variable costs	1000 VND/sow	1191.48	646.21	315.00	3295.00
Fixed cost	1000 VND/sow	1378.46	1032.28	325.83	6806.64
Output					
Total live weigh of fattened pig	kg/sow	915.44	184.30	500.00	1404.00

Note: 1) Sample size = 161, Own survey 2014

The results indicate that there are considerable variations in input usage. Of all the inputs, fixed cost shows the greatest variation with some farmers reporting expenses 20 times higher than their counterparts. This is because some household pig producers invest more in modernizing their barns than others. Feed expenses are the largest component of total cost, but they show the least variation with the greatest spenders only paying three times as much as more

frugal farmers. The variations of labor and other expenses are over 7 and 10, respectively. It is noted that households only use family labor using in pig production. Additionally, the physical output produced varies substantially, ranging from 500 kg to 1404 kg per sow. In conclusion, there are substantial variations in both the inputs and outputs, especially in the fixed cost and other variable costs of pig production. These variations indicate that there is poor management within the pig production sector.

The farmer and household characteristics used in the Tobit models are summarized in Table 2. Most farmers participate in a variety of agricultural activities, but 69% of them list livestock production as their main occupation. In addition, the average head-of-household has around 11 years of experiences with farrow-to-finish pig production. There are there main stages in a typical cycle of farrow-to-finish pig production (breeding time) includes around 4 months for raising sow before and during pregnancy, 1 - 1.5 months for raising sow and offspring from after delivery to before fattening period and around 3.5 - 4 months for fattening pigs. The average breeding time is around 9 months with a particular variation from 7.5 to 10.5 months. This shows that pig production much more depends on households' management. Furthermore, most households run only small scale operations with one to two sows per cycle and have about two people (who are usually the main laborers of the household) participating in pig production. These observations prove that pig production is very important for the households within the study area in terms of both employment and income and relies on managerial practices of households.

Table 2. Descriptive statistics for the household's socioeconomic characteristics

Variables	Unit	Description	Mean	St.dev	Min	Max
Household head characteristics						
Age (z1)	Years	Age of household head	47.88	9.31	28.00	72.00
Gender (z2)	Dummy	Take 1 if household head is male, zero otherwise	0.91	0.28	0.00	1.00
Education (z3)	Years	Years of schooling of household head	9.40	2.71	0.00	16.00
Main OC (z4)	Dummy	Take 1 if household head's main occupation is livestock production and zero otherwise	0.69	0.46	0.00	1.00
Experience (z5)	Years	Number of years household head engaged in farrow-to-finish pig production and zero otherwise	10.77	7.20	1.00	33.00
Training (z6)	Dummy	Take 1 if household head is trained in pig production and zero otherwise	0.56	0.50	0.00	1.00
Farm characteristics						
Lwperfat (z7)	Kg	Live weigh per fattening pig used as a measure o biological efficiency	90.76	9.70	70.00	120.00
Nosow (z8)	Numbers	The number of sows per cycle used as a measured of farm size	1.37	0.63	1.00	4.00
Breeding time (z9)	Months	The number of months in a full cycle	9.03	0.59	7.57	10.46
Family members (z10)	Numbers	The number of family members join in pig production	1.83	0.54	1.00	6.00
Pig income (z11)	Million VND	The income from pig of household in 2013	45.08	37.79	-100.00	180.00
Off-farm (z12)	Dummy	Take 1 if household has off-farm income and zero otherwise	0.72	0.45	0.00	1.00
Gene type (z13)	Dummy	Take 1 if household use local sow and zero otherwise	0.13	0.34	0.00	1.00
Artificial insemination (z14)	Dummy	Take 1 if household use artificial insemination and zero otherwise	0.48	0.50	0.00	1.00
Self-prepared (z15)	Dummy	Take 1 if household self-prepared feed for pig and zero otherwise	0.57	0.50	0.00	1.00
Access to credit (z16)	Dummy	Take 1 if household access to credit and zero otherwise	0.17	0.37	0.00	1.00
Access to veterinary (z17)	Dummy	Take 1 if household access to veterinary service and zero otherwise	0.84	0.37	0.00	1.00

Note: 1) Sample size = 161, Own survey 2014

2) Technical efficiency

Table 3 reports the frequency and percentage distributions of the TEcrs, TEvrs, and SE scores. First, the means of overall TEcrs and TEvrs for the sample of pig owners are 80.40% and 85.94%, respectively. Moreover, the range of the TEcrs means is from 0.5257 to 1.00 and that of TEvrs is from 0.5731 to 1.00.

It is shown that there are substantial differences in technical efficiency scores among household pig producers. According to the variable returns to scale (VRS) model, 31 out of the entire sample of 161 households operate at full efficiency. However, under the CRS model, only 13 households are fully efficient. Although some households can produce on the frontier of the farrow-to-finish pig production function, or very near to it, 45.96% of households still operate with overall technical inefficiency scores more than 20%. Furthermore, 31.68% of households exhibit pure technical inefficiency more than 20%. Based on above evidence, it is clear that some pig producing households are not only incapable of achieving technical efficiency, but also unable to produce on an optimal scale.

Table 3. Frequency and percentage distribution of technical and scale efficiency

Efficiency score	TEcrs		TEvrs		SE	
	No.	%	No.	%	No.	%
Less than 0.60	6	3.73	2	1.24	0	0.00
0.60 - 0.70	29	18.01	11	6.83	1	0.62
0.70 - 0.80	39	24.22	38	23.60	10	6.21
0.80 - 0.90	48	29.81	47	29.19	23	14.29
0.90 - 1.00	26	16.15	32	19.88	114	70.81
1.00	13	8.07	31	19.25	13	8.07
Mean	0.8040		0.8594		0.9364	
Std.Dev.	0.1180		0.1117		0.0709	
Minimum	0.5257		0.5731		0.6958	
Maximum	1.0000		1.0000		1.0000	

Notes: 1) Sample size 161, Own survey 2014

The mean of SE among farrow-to-finish pig keepers was 93.64% with a range from 0.6958 to 1.00. This means that, beyond their current resources, the household pig producers' size is nearly optimal. However, the households can still enhance their performance by an additional 6.4% by adjusting their scale. In terms of SE, 13 out of the 161 households produced under CRS.

The mean of TEvrs is lower than that of SE; this means that poor management, rather than operating scale, generates technical inefficiency in household farrow-to-finish pig production. This finding is similar to those of Mugeru & Featherstone (2008), who analyze backyard pig production in the Philippines. This evidence indicates that an increase in the pure efficiency score will

improve the overall efficiency score rather than the scale efficiency score. Thus, it may be concluded that household pig producers should enhance their performance by improving their management, rather than by changing the scale of their operation.

3) Factors affecting technical efficiency

Table 4 displays the results of the Tobit models, which determine the factors that affect TEvrs and SE in farrow-to-finish pig production.

According to Gujarati & Handeshøyskolen (2011), the coefficient on an independent variable in a Tobit model cannot be interpreted as the marginal effect of that variable on the mean of the observed dependent variable, Y_i . This is because the coefficient will have two effects: the first being on the mean of the observed dependent variable, Y_i ; the second being on the probability that the latent variable, Y_i^* , will actually be observed. However, the sign on this coefficient can show the relationship between the explanatory variables and the dependent variable.

Table 4. Results of Tobit regression on technical and scale efficiency

Variables	TEvrs		SE	
	Coefficient	St. Error	Coefficient	St. Error
Constant	1.2979 ***	0.1880	0.8539 ***	0.1041
Gender	-0.0092	0.0368	0.0277	0.0204
Age	-0.0019	0.0012	-0.0004	0.0007
Education	-0.0018	0.0039	0.0038 *	0.0022
Main OC	0.0271	0.0231	0.0106	0.0131
Experience	0.0033 **	0.0016	-0.0004	0.0009
Training	0.0128	0.0225	0.0104	0.0127
Lwperfat	0.0022 *	0.0012	0.0016 **	0.0007
Nosow	-0.0027	0.0186	-0.0094	0.0105
Breeding time	-0.0612 ***	0.0185	-0.0123	0.0103
Family	0.0086	0.0197	0.0224 **	0.0111
Pig income	0.0004	0.0003	0.0003 *	0.0002
Off-farm	-0.0137	0.0248	0.0018	0.0138
Access to credit	-0.0539 **	0.0270	-0.0393 ***	0.0151
Self-prepared	0.0016	0.0213	-0.0076	0.0119
Access to veterinary	-0.0243	0.0291	-0.0347 **	0.0165
Gene	-0.0385	0.0306	0.0225	0.0173
Insemination	-0.0086	0.0204	0.0021	0.0115
Log-likelihood	61.3621		176.8694	

Note: 1) ***, **, * indicate differences from 1%, 5% and 10% level, respectively.

2) Sample size = 161, Own survey 2014

In general, two parameters are found to be significant for both TEvrs and SE and they are live weight per fattened pig (lwperfat) and access to credit. The former is used as a measure of biological efficiency and has a positive impact on the efficiency scores. This indicates that households who produce more kgs per fatter pig could achieve a higher technical efficiency scores. In addition to, Rowland et al. (1998), who study farrow-to-finish pig production in

Kansas, find that pounds of pork produced per litter per year (used as a measure of biological efficiency) significantly and positively influence TEvrs but negatively affect SE without significance. The reasons for this might be that the sample households could optimal breeding, the timely administration of vaccinations, and segregated early weaning could all contribute to this effect. In contrast the findings of Mugeru & Featherstone (2008), the results indicate that access to credit has a negative impact on both efficiency scores. The reason might be because households accessed to credit to invest more in expansion and modernization their farm compared to households who did not access to credit. Moreover, the scales of the formers are not satisfied the conditions for getting credit's support from the government with low interest rate and long borrowing time. These makes their cost of production is higher than that in households who did not access. Thus, households who had accessed to credit obtained lower technical efficiency than those who did not have access.

Aside from the two aforementioned variables, the only factors that affected TEvrs were experience and breeding time. Experience had a positive and significant impact on TEvrs, meaning that the more experience a household head had in farrow-to-finish pig production, the more efficient the household was. This result supports the work of Mugeru & Featherstone (2008), who found similar effects in backyard pig production in the Philippines. This effect is quite natural in agricultural activities, especially in developing countries, because more skilled farmers are better able to manage their production and achieve greater efficiency. Moreover, experience plays a particularly major role in farrow-to-finish pig production as it requires the use of a wide variety of special techniques, such as sow and piglet care and fattening. Conversely, breeding time was found to have a negative effect; that is, the longer the breeding time is, the lower TEvrs is. In full cycle pig production, the breeding time mainly depends on the time it takes to raise a sow before it may be impregnated, the time necessary to wean piglets, and the fattening time. Households were inefficient because they took too long to impregnate their sows and to wean their piglets, which were ultimately infected with various diseases as well. It should be noted that none of the other variables had a significant effect on TEvrs. Though it is thought that the number of sows (representing the size of a household's operation) should positively and significantly affect TEvrs, the results

indicate that its effect is negative as well as insignificant. This is inconsistent with the results reported by Galanopoulos et al. (2006), who showed that the number of sows had a positive and significant impact on TEvrs. One potential reason for this study's finding could be that the farms' sizes were captured by multiple variables, like the number of sows and the number of fattening pigs; this suggests that larger households are not necessarily more efficient than their smaller counterparts.

Education, family members, pig income, and access to veterinary services all affected only SE. The results show that more educated farmers run their businesses on a more efficient scale than less educated farmers, which concurs with Mugeru & Featherstone (2008) findings. However, Galanopoulos et al (2006), who study commercial pig farming in Greece, found that education was negative and insignificant. It could be that education plays a greater role in agriculture in developing countries because well-educated farmers might have better management skills and greater access to information. In addition, households with more family members working in pig production and more income from pigs tend to have a greater SE score. Lastly, access to veterinary has a negative and significant impact on SE. This contradicts Mugeru & Featherstone (2008) findings, as they reported that Filipino farmers who were visited by a veterinarian had higher SE scores those who were not visited. This may be because veterinary services in the study area were ineffective. Households who had access to veterinary care usually only received government support when their stock contracted diseases. They also elected to forego veterinarians' advice on husbandry techniques as they believed that the veterinarians were both unqualified and likely to spread diseases from farm to farm. No other factors were found to have a significant impact on SE.

4. Conclusion and implication

Households continue to produce most of Vietnam's pork supply; however, they must increase their performances despite facing challenges such as their small scale, limited resources, a lack of support, and poor husbandry techniques. Thus, they must endeavor to become more efficient at producing pigs.

First, this study showed that the mean of overall technical efficiency in household farrow-to-finish pig production was 80.40%; this means that households could

reduce their inputs by nearly 20% and still produce the same level of output. Furthermore, this study found indications that the technical inefficiencies in pig production were mostly the product of low TEvrs rather than low SE. Thus, it may be concluded that households should concentrate on improving their managerial skills rather than changing their scale in order to enhance their performance.

Secondly, the main factors that affect technical efficiency in pig production are the live weight per fattened pig, breeding time, education, experience, family members joining in pig production, pig income, access to credit, and access to veterinary services.

From these results, several implications may be drawn for both households and the government. First, households could reduce their inputs and produce large quantities fattened pigs by utilizing breeding centers, which provide clear information on husbandry. Pig producers may also enhance their skills through training programs and by studying the best pig producers. Another option for inefficient households is to reduce their breeding time by taking better care of the sows before they become pregnant and by weaning their piglets earlier (about 30 days after birth).

Second, government must emphasize that while it wishes to increase the production of small-scale household operations, that the pig industry is “changing from small, family based farm to large, intensive and commercial farm” (Vietnamese Prime Minister, 2008). Furthermore, they should also inform the public of breeding sources and specifications. The government could also supply credit at a lower interest rate and for longer periods to households with a high proportion of income from pigs and with more family members participating in pig production; this would assure that even households with very small-scale operations could still earn a living from pig production. Additionally, an effective veterinary service should be made available to pig producers in order to better prevent the spread of diseases.

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