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Performance of Fish Farms in Vietnam–Does Financial Access Help Improve Their Cost Efficiency?

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Abstract: For a common small- to medium-sized fish farm in an agricultural-based economy, monitoring costs is very important, since financial constraints are always a problem for these farmers. This will be thus easier if the farmers can get access to external funds. This paper used data envelopment analysis (DEA) to examine the technical efficiency, cost efficiency and allocative efficiency of 639 fish farms in the Red River Delta (RRD) in Vietnam in 2018 to see how fish farmers control their costs and if financial access can really help in this matter. We found that these fish farms were very inefficient, meaning that they did not succeed in monitoring and allocating their costs and resources. Among the factors that could improve their efficiency, we found that developing the rural banking system to provide more financial access for RRD fish farms is an important solution.

Keywords: cost efficiency; data envelopment analysis; fish farm; financial access; Vietnam; Red River Delta (RRD); aquaculture

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1. Introduction

Vietnam is arguably an agricultural-based economy, since this sector still accounts for more than 15% and 40% of the country's gross domestic product and labor force, respectively (General Statistics Office 2017). Thanks to its tropical climate, more than 1 million km^2 of inland surface water and ~3260 km of coastline, Vietnam's aquaculture has played a growing role in the country's agriculture sector (World Bank 2017). For example, the aquaculture's farmed area doubled between 1995 and 2013, while its production volume increased up to eight times (World Bank 2017). This trend is projected to continue, with aquaculture's output expected to reach about 4.5 million tons in 2020, contributing around 3.5% to the national gross domestic product and creating jobs for nearly 5 million people, with income three times higher than at present (Japan International Cooperation Agency 2013; Vietnamese Government 2013). The development of aquaculture is helping the country in many ways, including boosting exports of aquaculture products and improving rural farmers' livelihoods (Duc 2009). For pro-aquaculture economies such as Vietnam, improving the efficiency and performance of its fish farms is an important matter.

Data envelopment analysis (DEA) is a popular tool for efficiency and performance assessments in the agriculture and aquaculture sectors (Arita and Leung 2014; Färe et al. 1985; Kaliba and Engle 2006; Sharma and Leung 2003; Thiam et al. 2001) since it does not require an a priori production function and it can handle multiple outputs (Nguyen et al. 2019). Its counterpart, stochastic frontier analysis (SFA), is based on regression and thus can only deal with a single dependent variable or output (Bukenya et al. 2013; Kim et al. 2011). Most DEA studies on aquaculture farms analyze how efficiently the sampled farms transform their production inputs such as labor, feed or fingerlings into outputs such as fish yields or sales (i.e., technical efficiency) (Arita and Leung 2014; Kaliba and Engle 2006; Oluwatayo and Adedeji 2019; Pham et al. 2018; Thiam et al. 2001). In this sense, to improve their efficiency, aquaculture farmers can minimize the use of their inputs (given the same outputs), maximize the production of their outputs (given the same inputs), or try to do both. From a management perspective, it is arguable that controlling the input side is easier and more practical than monitoring the output side (Iliyasu et al. 2016; Ngo et al. 2019). Inhibitory, input-oriented technical efficiency studies assume that unit prices of the same input should be identical or similar among the farms examined (i.e., the law of one price), so that by controlling and minimizing the number of inputs, farmers can minimize the costs or resources used on their farms. This assumption, however, is incorrect, as prices are very flexible and there are heterogeneity issues related to those inputs and outputs, such as their quality, retail vs. bulk purchasing, seasonal effects or even bargaining power between sellers and buyers. For example, Mountain and Thomas (1999) pointed out that in the US, labor prices (in the banking system) can make a six-fold difference. This difference is likely to be more significant in developing countries than in developed ones (Ngo and Tripe 2016). In line with the argument that the aquaculture sector is characterized by high price variability (Dresdner and Estay 2016), Asche and Oglend (2016) also noted that the composition of the feed itself can vary among different feeds types, although they are all based on marine proteins (fishmeal), vegetable proteins, fish oil, vegetable oil and carbohydrates. For this study, we particularly found that the (output) fish prices could differ by only 1.2- to 2.1-fold, whereas the input prices could differ by 1.8- to 31.4-fold among the sampled farms (see Table 1 and Section 3.2 below). This suggests that the assumption of single input price(s) within the input-oriented technical efficiency does not hold, and that one should be aware of the impact that unit prices can have on the total cost of aquaculture farms. Therefore, it will be important to examine fish farms in terms of cost efficiency rather than input-oriented technical efficiency. Additionally, the former approach allows one to study not only the input prices and cost efficiency of the sampled aquaculture farms but also the allocative efficiency (i.e., how those farms allocate their resources) (Sharma et al. 1999).

The Red River Delta (RRD) of northern Vietnam, especially peri-urban Hanoi and the adjacent provinces, is one of the largest deltas in Southeast Asia (Phan et al. 2011). In Vietnam, the RRD is a rich agricultural area (Phan et al. 2011) and its aquaculture sector is rapidly changing and improving (Edwards 2010). All changes require investment, and financial access has become crucial for fish farmers. Previous agricultural studies, such as Hazarika and Alwang (2003), Binam et al. (2004) and Afrin et al. (2017) have shown that farmers who had access to more funds outperformed their counterparts. Limited attention has been paid to the field of aquaculture, though, maybe because of data limitations. For example, it has been shown that in rural areas of Vietnam, in general and in the RRD in particular, the development and expansion of banks, both policy and commercial banks, still falls short of the requirements: nearly 50% of farmers and households in the RRD have to seek funds from informal creditors (Barslund and Tarp 2008). As pointed out in other similar situations, informal credit lacks transparency and accountability, with money lenders usually demanding high interest rates under onerous conditions to the borrowers/farmers (Rahman et al. 2002; Ruddle 2011). However, farmers still have to rely on those sources because they do not have enough collateral (Ta et al. 2019). Therefore, collecting and analyzing information regarding the (formal and informal) financial access of farmers is an important yet difficult task. Vietnam has been trying to develop and promote its rural credit markets (Ta et al. 2019), and this fact motivates us to examine how efficient the RRD's fish farmers are at using their money and if official financial access can help to improve aquaculture's performance.

Table 1. Descriptive statistics for variables used in this research.

Item	Variable	Mean	Min	Max
Outputs				
Fish yield (*Labeo rohita*, kg)	y_1	2570.55	42	13,000
Fish yield (*Ctenopharyngodon idella*, kg)	y_2	666.11	0	6000
Fish yield (*Hypophthalmichthys* spp., kg)	y_3	658.84	0	20,000
Fish yield (*Tilapia mozambiccus*, kg)	y_4	1817.81	0	24,000
Fish yield (*Cyprinus carpio*, kg)	y_5	1308.97	0	16,800
Inputs				
Fingerlings (kg)	x_1	6057.78	26	46,000
Feed (kg)	x_2	6805.79	1.5	97,632
Labor (hours)	x_3	897.08	12	11,535
Machinery and equipment (units)	x_4	5.08	2	30
Chemicals (kg)	x_5	580.44	6	7296
Input prices				
Fingerlings (thousand VND/kg)	w_1	11.64	2.43	20.00
Feed (thousand VND/kg)	w_2	10.39	4.00	38.28
Labor (thousand VND/hour)	w_3	221.99	114.29	3592.40
Machinery and equipment (thousand VND/unit)	w_4	7500.95	5500.00	10,000.00
Chemicals (thousand VND/kg)	w_5	4.06	2.37	7.89
Determinants of efficiency				
Gender (equals 1 if the head of the farm is a female and 0 otherwise)	z_1	0.19	0	1
Experience (years)	z_2	4.96	1	9
Family size (persons)	z_3	4.70	3	9
Pond size (m^2)	z_4	1759.20	108	12,000
Ease of financial access (equals 1 if the farmer finds it easy to borrow money from official creditors and 0 otherwise)	z_5	0.15	0	1

In this sense, this paper contributes to the aquaculture efficiency literature, providing useful information on the sampled fish farms in terms of their allocative efficiency and cost efficiency. It also helps to explain the role of financial access in improving the efficiency and performance of the farms. Therefore, this is the first study to examine aquaculture farms in the RRD area in Vietnam in terms of technical, cost and allocative efficiency under the impact of financial access.

The rest of the paper is structured as follows. Section 2 provides a short literature review. Section 3 describes the methodology, variables and data used in this research. Section 4 presents and discusses the empirical results, and Section 5 concludes the paper.

2. Relevant Literature

DEA is a non-parametric technique that envelopes the best-practice decision-making-units (DMUs) into a piecewise-linear frontier and then compares all other DMUs to this frontier (Farrell 1957). In this sense, DMUs that lie on the frontier are considered efficient, while the rest are inefficient. Since the DEA frontier is based on the observed DMUs, it does not require any a priori specification of the production function and is therefore flexible (Ngo and Le 2019). The ability to handle multiple outputs also makes DEA more popular in the field of agriculture (Färe et al. 1985; Mao and Koo 1997; Thiam et al. 2001), fisheries (Oliveira et al. 2010; Shen et al. 2013; Zibaei 2012) and, increasingly, aquaculture (Iliyasu et al. 2014; Oluwatayo and Adedeji 2019; Pham et al. 2018; Sharma et al. 1999; Sharma and Leung 2003).

Sharma et al. (1999) measured the DEA revenue efficiency of 115 fish farms in eight provinces in China for 1985. The DEA model used mixed inputs (both quantities and costs) and quantity outputs, as well as output prices, to estimate the overall (revenue) efficiency, technical efficiency and allocative efficiency of the sampled farms. The allocative efficiency helped to define the optimum stocking and input levels for these farms. In particular, Chinese fish farms were able to save up to 11% of their costs on average (by increasing the stocking rate of grass carp and decreasing that of black carp) while increasing production by about 50% and revenue by 45%. This conclusion, however, was based on the output prices of the fish yield (assuming they can all be sold) but not the input prices of the real inputs, and thus could have been biased.

Zibaei (2012) analyzed 520 Iranian wooden fishery vessels in 2007 via metafrontier DEA. The technical DEA model used four inputs (number of crew numbers, number of fishing days, engine horsepower of the vessel and number of nets) and one output (the catch of each vessel). Iranian fishery vessels were found to be inefficient with a mean technical efficiency score of 0.702 (if using regional frontiers) or 0.476 (if using the meta-frontier). This study, however, did not address the impact of financial access on performance.

A recent study by Iliyasu et al. (2016) demonstrated that there have been only nine DEA applications compared with 29 SFA applications in studies on aquaculture. Nevertheless, these studies have shown that fish farms are generally inefficient: the average efficiency score of SFA studies is 0.68, whereas that of DEA studies is 0.61. More important, Iliyasu et al. (2016) pointed out that most of the studies did not only examine the efficiency of aquaculture farms, but also tried to explain the determinants of this efficiency and to improve the performance of those farms. In this sense, examining the role of financial access, among other factors, on the performance of RRD fish farms may contribute to the literature, not only in terms of empirical findings (i.e., new data on Vietnam), but also in terms of methodology, by introducing a new variable.

3. Methodology

3.1. The First Stage: Cost Efficiency DEA

The idea of DEA can be traced back to the seminal work of Farrell (1957). Abraham Charnes and Rhodes (1978) introduced the use of linear programming to solve the DEA problem in a constant-return-to-scale situation; later, Banker et al. (1984) extended the model to the variable-return-to-scale situation. Since there are differences in the scale of operations among our sampled farms, we have adopted the variable-return-to-scale approach in this study and express it as follows.

Following Coelli (1996), let us assume that we have a set of n fish farms (DMU j, $j = 1, \ldots, n$) using s inputs (x_i, $i = 1, \ldots, s$) to produce m outputs (y_r, $r = 1, \ldots, m$). If we use quantity data only, the input-oriented technical efficiency of the fish farm k is defined as:

$$TE = \min_{\theta,\lambda} \theta, \tag{1}$$

subject to $y_i \leq Y\lambda$, $\theta x_i \geq X\lambda$, $T\lambda = 1$ and $\lambda \geq 0$, where λ represents the associated weights of the inputs and outputs of the fish farm k and T is an $nx1$ vector of ones.

When the input prices are known, the cost-minimization level of all fish farms can be estimated as:

$$\min_{x_i^*,\lambda} w_i^T x_i^*, \tag{2}$$

subject to $y_i \leq Y\lambda$, $x_i^* \geq X\lambda$, $T\lambda = 1$ and $\lambda \geq 0$, where w_i is the vector of input prices for the ith farm, T denotes the transpose function and x_i^* is the cost-minimizing vector of input quantities for the ith farm, given the input prices w_i and the output level y_i.

The cost efficiency of each farm is consequently calculated as the ratio between the minimum cost (derived from Equation (2)) and the observed cost:

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

The allocative efficiency is:

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

3.2. The Second Stage: Tobit Regression

With the first-stage results, there are two ways to improve the performance of the examined fish farms. The first one is to adjust the inputs and/or outputs of each inefficient farm towards the frontier. For example, Sharma et al. (1999) suggested that inefficient Chinese fish farms adjust their outputs by increasing grass carp and decreasing black carp stocking rates. This can be seen as internal adjustment of the farms. The second one involves determining external factors that can affect efficiency through a second-stage regression, where the efficiency scores are regressed against a set of environmental factors such as government policy, farm characteristics, market competition, etc. In this sense, by adjusting those external factors, one can also improve the efficiency of the farms.

By definition, efficiency scores (i.e., the dependent variable in this regression stage) are bounded between 0 and 1. Therefore, the ordinary least squares method is inadequate in this case and Tobit regression (Tobin 1958) is more appropriate. The mathematical Tobit regression used in this study is as follows:

$$EF = f(z; \beta) + \varepsilon, \tag{5}$$

where EF represents the technical efficiency (TE), cost efficiency (CE) and allocative efficiency (AE), respectively; z is a vector of external factors; β is a vector of parameters to be estimated and ε is the random error.

3.3. Data and Variables

Our survey was conducted in 2018 as part of a joint-project between Vietnam's Ministry of Agriculture and Rural Development and the National Institute of Agricultural Planning and Projection. It used a multistage sampling technique to select participants from RRD fish farms and includes the most recent data on RRD aquaculture. (Note that different surveys cover different samples and thus we could not carry out a longitudinal or panel data analysis.) Our survey covered 1063 fish farms but only 639 farms had full records for their input prices. Table 1 presents the descriptive statistics of our data.

The RRD fish farms provide several types of fishes to the local and regional market, including *Labeo rohita* (y_1), *Ctenopharyngodon idella* (y_2), *Hypophthalmichthys* spp. (y_3), *Tilapia mozambiccus* (y_4) and *Cyprinus carpio* (y_5). To do that, they need to purchase fingerlings (x_1), purchase the feed (x_2), hire labor (x_3), hire or purchase machinery and equipment (x_4), and purchase fertilizers and medicines (x_5). These inputs are commonly used in the field of aquaculture efficiency (Iliyasu et al. 2014; Iliyasu et al. 2016; Pham et al. 2018; Sharma and Leung 2003; Ton Nu et al. 2018). The corresponding input prices of these variables vary widely between the maximum and minimum values (see Table 1), suggesting that cost efficiency analysis can provide more insights into the examined farms than the input-oriented approach.

To determine the factors that can affect RRD fish farms' efficiency, we also collected data on the gender of the head of the farm (z_1), years of experience working in the aquaculture sector (z_2), the size of the family (z_3), the size of the ponds (z_4) and ease of financial access (z_5). Except for the last one, these factors have been also commonly used in other aquaculture studies, such as Iliyasu et al. (2016) and Ton Nu et al. (2018). For z_5, since all farmers had to rely on external loans, we simply asked the farmers if it was easy for them to obtain external funds from official creditors (e.g., banks, credit unions) during their operations. We acknowledge that detailed information on financial access would provide a better understanding of the situation; however, this information is difficult to collect, especially data on unofficial loans—farmers did not want to provide this information because of the potential to affect their future ability to obtain those loans. In this sense, we can assume that farmers who found it is difficult to obtain loans from official creditors turned to the unofficial channel, and the introduction of z_5 is still an important contribution of our paper. As observed from Table 1, the mean of z_5 is 0.15, suggesting that the majority of our sampled RRD fish farmers were relying on those unofficial loans, consistent with Barslund and Tarp (2008).

4. Results and Discussion

First, we report the results of the first-stage cost efficiency DEA in Table 2, in which the first three rows (technical efficiency (TE), cost efficiency (CE) and allocative efficiency (AE)) were calculated via Equations (1), (3) and (4), respectively; the last row ("TE in the literature") is the average of all TE values derived from previous aquaculture studies.

Table 2. Average efficiency scores of Red River Delta fish farms in 2018.

Efficiency	Mean	Standard Deviation	Min	Max
Technical efficiency (TE)	0.635	0.237	0.105	1
Cost efficiency (CE)	0.311	0.241	0.014	1
Allocative efficiency (AE)	0.486	0.280	0.017	1
TE in the literature [1]	0.613	0.205	0.250	0.960

[1] Calculated from a summary of previous DEA studies (Iliyasu et al. 2016).

Although the TE of RRD fish farms was found to be similar to that of other fish farms in the world, with an average value of 0.635, the CE and AE were much lower at 0.311 and 0.486, respectively. This indicates that the average fish farm in RRD area uses 68.9% (i.e., 1–0.311) of their costs inefficiently, including 51.4% (i.e., 1–0.486) relating to resource allocation. The additional information of CE and AE therefore raises the question of how the farmers control their money and costs, and thus, how to help them improve their cost and allocative efficiency.

Table 3 reports the results of the second-stage Tobit regression. Several important conclusions can be drawn on the basis of this table, as explained below.

Table 3. Determinants of Red River Delta fish farms' performance.

	TE		CE		AE	
	Coef.	S.D.	Coef.	S.D.	Coef.	S.D.
Constant	0.937 ***	0.099	0.688 ***	0.086	0.727 ***	0.099
Gender (z_1)	−0.043	0.027	−0.047 **	0.023	−0.038	0.027
Experience (z_2)	0.018 ***	0.006	0.026 ***	0.005	0.041 ***	0.006
Family size (z_3)	−0.015	0.014	−0.008	0.012	0.006	0.014
Pond size (z_4)	−0.042 ***	0.010	−0.067 ***	0.008	−0.069 ***	0.010
Ease of financial access (z_5)	−0.028	0.030	0.063 **	0.026	0.106 ***	0.030
Number of observations	639		639		639	
LR $\chi^2(5)$	33.620		100.850		105.780	

Notes: TE: technical efficiency; CE: cost efficiency; AE: allocative efficiency; Coef.: coefficient; S.D.: standard deviation; LR: likelihood ratio. ** and *** denote the 5% and 1% levels of significance, respectively.

First, farmers with more experience tend to perform better. This is not a surprise, and is in line with many other studies (Cinemre et al. 2006; Iliyasu et al. 2016; Kaliba and Engle 2006; Pham et al. 2018). The consistent results across all three indicators or models in Table 3 confirm once more that knowledge is very important in agriculture (Nguyen et al. 2019). Although the RRD fish farms are seen as comparatively young farms (average years of experience is 4.96, as in Table 1), there is potential for these farms to improve their efficiency in the future. Nguyen et al. (2019) also suggested that training and/or technical guidance and support from local government could help in this situation.

Second, farms with bigger ponds tend to be less efficient than farms with smaller ponds. This is understandable, since bigger ponds mean more inputs and higher costs. The low level of allocative efficiency (AE) and cost efficiency (CE), as reported in Table 2, suggest that RRD fish farms were not efficient in terms of allocating their inputs as well as managing their costs. It is therefore difficult for those with bigger ponds to convert the inputs and costs into the desired outputs. This result is in line with what has been found in the agriculture sector ((Desiere and Jolliffe 2018; Rada and Fuglie 2019); i.e., the inverse size-productivity relationship, (van Zyl et al. 1995)) and in the aquaculture sector (Cinemre et al. 2006; Kaliba and Engle 2006) in developing countries. Consequently, one could argue that RRD fish farms should reduce their pond size to both decrease the associated costs and the management burden for farmers.

Third, except for the TE model, both the CE and AE models show a positive relationship between financial access and efficiency. This finding strengthens the justification of cost efficiency analysis: if one only uses technical efficiency measures, he or she may not explain the impacts of financial access on RRD fish farms' performance, or the explanation may be biased. More important, the results show that for the development of the aquaculture sector, financial support from local banks and credit institutions is crucial. Consequently, the development of the rural banking system, e.g., in terms of bank branches, processing of applications and number of loans, should be emphasized in developing and/or pro-aquaculture economies such as Vietnam. This finding therefore contributes to the aquaculture efficiency literature, because similar findings were found in the agricultural sector (Afrin et al. 2017; Binam et al. 2004; Hazarika and Alwang 2003), but not specifically for fish farms.

Fourth, it seems that fish farms with female heads have a greater likelihood of decreasing efficiency, similar to the findings of Oluwatayo and Adedeji (2019). One possible explanation for this finding is that aquaculture requires fairly continuous labor input, not to mention the hard labor needed for pond construction and maintenance (Onumah et al. 2010). An earlier study by Voeten and Ottens (1997) also showed that in the RRD, men were more involved in the management and operation of aquacultural activities, and thus it is reasonable to argue that men play an important role in improving the efficiency of the fish farm.

5. Conclusions

This paper examined the performance of 639 fish farms in 2018 in the RRD area in terms of (input-oriented) technical efficiency, cost efficiency and allocative efficiency. This was done by following a two-stage approach where cost DEA was applied in the first stage, with the results being used as dependent variables in the second stage to determine the factors that may have an impact on the efficiency of the examined farms. In the first stage, was is argued that the cost DEA provided more insights into fish farms, especially when the prices of the inputs used by those farms did not follow the 'law of one price'. In the second stage, besides some commonly used factors such as the gender of the head of the farm or years of experience, we also examined the role of financial access on the farm's efficiency, since this positive relationship has been found in the agriculture sector generally (Afrin et al. 2017; Binam et al. 2004; Hazarika and Alwang 2003) but has not previously been found in the field of aquaculture, especially in the RRD area in Vietnam.

Our empirical results showed that RRD fish farms were highly inefficient in terms of AE and CE: the average farm allocated 51.4% of its resources inefficiently, which contributed to 68.9% of costs not being optimized. Four important factors that may help to improve the efficiency of RRD fish farms are: (i) increasing the farmers' experience and knowledge, maybe through training and/or technical guidance and support; (ii) reducing pond size to both decrease the associated costs and the management burden for farmers; (iii) providing government help for developing the rural banking system so that farmers can get easier access to loans; and (iv) encouraging more participation by males in the aquaculture sector, since this sector requires fairly continuous labor input and hard work. Consequently, farmers and policy makers can use a mixture of strategies for improving efficiency. For example, policy makers can combine the last two factors (i.e., supporting rural banking or encouraging male fish farmers), or farmers can focus on the second factor (pond size) when they face technical and financial restrictions.

Our research is not without limitations. Although we only focused on the RRD area, it would be interesting and meaningful to extend the research scope to other regions and deltas for a broader understanding of the aquaculture sector in Vietnam. Other extensions could consider other time periods, fish types or farm types. More observations will therefore allow for the inclusion of more variables of interest. Extensions in terms of methodology, such as the use of bootstrap DEA, profit DEA, SFA, etc. may also be important.

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