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Technical Efficiency and Social Capital in Tilapia Aquaculture Production in Nueva Vizcaya, Philippines

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Abstract

This paper focuses on tilapia aquaculture production in Nueva Vizcaya, Philippines. Primary data were collected from a field survey. Apart from investigating the effects of technical efficiency variables (e.g., operator's experience, age of fishpond owner, and frequency of visits of the manager) on the production frontier, this study also incorporated social capital variables (e.g., social network and trust) as additional factors affecting the frontier. A cross-sectional analysis of 202 fishpond operators from the 10 municipalities in the province was conducted using stochastic frontier analysis, where the error component consists of both the usual two-side random shocks and the one-side technical inefficiency shocks. Results suggest that social network has an indirect but significant relationship to aquaculture harvest. On the other hand, harvest is significantly influenced by community trustworthiness, which implies that fish farmers who do not readily lend money to members of their community are able to increase their harvest because they can devote their funds to production activities.

Keywords: stochastic frontier, social capital, social network, technical efficiency, tilapia

JEL Code: Q12, Q22

Introduction

Background and Significance of the Study

With deep concern for the impacts of climate change and the consumption pattern of the rising population to agricultural food production, there is an increasing global initiative to reduce hunger and alleviate poverty. Between 2009 and 2050, the world population is expected to have increased by 2.3 billion, and this growth is projected to happen mostly in developing countries. This projected growth would require an almost double production to feed the population (FAO 2009a). The World Bank (2013, p. vii) observed that

Feeding an expected global population of 9 billion by 2050 is a daunting challenge that is engaging researchers, technical experts, and leaders the world over. A relatively unappreciated, yet promising, fact is that fish can play a major role in satisfying the palates of the world's growing middle income group while also meeting the food security needs of the poorest.

Fish is a primary source of animal protein. In 2008, 115 million tons of fish were consumed from a total of 142 million tons of world fish supply. Of the total world fisheries production, 52.5 million tons represents aquaculture fisheries. Aside from being a food source, the fish sector is also a source of income, livelihood, and employment for millions of people around the world, which may be directly engaged, full time or part time, in both capture and aquaculture fisheries (FAO 2010).

World aquaculture production has grown by 154 percent between 2000 and 2015, or at an annual growth rate of 9.62 percent, in terms of volume. It represents a 53 percent share to total fish production, while capture fisheries contributed 47 percent in 2015. Capture fisheries has declined by 1.5 percent from 96.36 million MT in 2000 to 94.93 million MT in 2015, with a negative annual growth rate of 0.09 percent (FAO 2009b). This is caused by overexploitation, climate variability, fuel

costs, and pollution. According to Pedini (2000), the importance of aquaculture is heightened, considering the fact that capture fisheries would probably be unable to meet the demand for fish of the expanding population.

In five coastal communities in the Philippines, poor and non-poor households derive income from aquaculture. Evidence also shows that there is some degree of social mobility, wherein some poor people manage to establish themselves as aquaculture producers (Irz and Stevenson 2009). The Philippines' total fish production (capture and aquaculture fisheries) increased from 2000 to 2015 with an all-time high record in aquaculture production in terms of volume achieved in 2011 at 2.6 MT. Between 2000 and 2015, the growth of aquaculture was at 113 percent, while capture fisheries increased by only 12.21 percent between 2000 and 2015 (PSA 2016a; BAS 2009).

This study focuses on aquaculture production in Nueva Vizcaya, a province located in the southernmost part of the Cagayan Valley Region (Region 2) and situated in the center of Northern Luzon. Located in the northeastern part of the Philippines and bounded by mountain ranges, Cagayan Valley is home to a community of fishpond farmers. Total fishery production in the region from 2000 to 2012 increased by more than 70 percent, with an annual growth rate of 5.43 percent (PSA 2013). The Philippine Statistics Authority (PSA) reports that aquaculture tripled its production from 5,000 MT to more than 15,000 MT from 2001 up to 2009; although the annual growth rate reduced from 13.1 percent in 2011 to 5.6 percent in 2012. Production performance in agriculture and fisheries have always been challenged by the continuous threat of disasters and weather disturbances (NEDA-RDC 2 2011).

Nueva Vizcaya is a watershed haven with 70 percent forestland surrounded by mountain ranges—the Sierra Madre in the east, Caraballo in the south, and Cordillera in the west. It is basically an agricultural province with palay and corn as primary crops. Aquaculture started to flourish in the province when Mozambique tilapia (*Oreochromis mossambicus*) fingerlings became commercially available in early 2000. The number

of fishpond owners increased in the municipalities of Bagabag, Bayombong, Bambang, Diadi, Solano, and Quezon (Bisquera 2016, pers. interview).

Aquaculture production in Nueva Vizcaya grew from 2000 up to 2015. In terms of volume, aquaculture production has almost quadrupled between 2000 and 2015 or at an annual growth rate of 25.8 percent. It enjoyed an impressive growth rate of 17 percent from its 2011 production level of 978 MT to 1,145 MT in 2014. However, total fish production plummeted from 1,065 MT in 2009 to 827 MT in 2010, and from 1,145 MT in 2014 to 736 MT in 2015. According to the key informants interviewed, the decline in fish production can be associated with the early onset of the El Niño phenomenon, which prolonged the dry spell, the super typhoon Lando, and the natural entry of predators, specifically, rice paddy eels.

Between 2011 and 2015, the Nueva Vizcaya population increased at a rate of 5.7 percent, while fish production declined at 6.3 percent. With the increasing demand for fish protein due to the growing population vis-a-vis declining fish production, Nueva Vizcaya imports parts of its fish supply from neighboring provinces.

Against this background, this study aims to determine if there is potential for further growth of tilapia pond farming in Nueva Vizcaya, and the factors that can counter the constraints, such as technology advances for the intensification of aquaculture production (i.e., the use of fertilizer), skills and experience of fish farmers, productivity of inputs, and social capital.

Studies have shown that production and profitability in aquaculture are constrained by different barriers, such as poor infrastructure; size of the pond; lack of skilled labor and technical capability (Brummett 2011); lack of constant water supply (Bush and Kosy 2007); limited information, market, and access to credit (Brummett 2011; Irz and Stevenson 2009); credit market failures (Ellis 2000); as well as environmental factors (Bjornlund, Rooyen, and Stirzaker 2016; Bush and Kosy 2007).

However, the literature on the relationship between aquaculture production and social capital (along with other dimensions, particularly access

to credit and social network) remains limited. Secondary data on aquaculture production and the sociodemographic profile of fisherfolk practicing the system, at the provincial level, are also limited and obsolete. Hence, there is room for additional empirical inquiry, which this study aims to fill.

Social capital, as defined by Ellis (2000), is “the social networks and associations in which people participate, and from which they can derive support that contributes to their livelihoods.” It is a multi-dimensional concept, a combination of structures (i.e., networks) and cultural components (i.e., trust, norms of reciprocity) (Nenadovic and Epstein 2016). Social networks, as defined by Orchard, Stringer, and Quinn (2015) citing Abbasi, Chung, and Hossain (2012), consist of two or more actors such as individuals, households, or organizations that are connected through one or more relations. As a member of a fisher organization in the province of Nueva Vizcaya, one can borrow as much as PHP 50,000¹ worth of fingerlings and feeds to be paid after harvest, according to a key informant.

One of the studies that looked into the relationship between aquaculture income and social capital is one by Islam, Yew, and Viswanathan (2014). They found that trust as a proxy variable for social capital assets was inconclusive and resulted in an insignificant relationship with income of the fishers. The purpose of this study is to ascertain the relationship between aquaculture production and social capital, and with other dimensions, such as credit accessibility and social networks.

Technical efficiency itself was not estimated in this model. Rather, technical efficiency variables were included in the empirical methodology as determinants of the production level of the fishpond operators, just as social capital variables were also treated as inputs to production. Neither were estimates of technical inefficiency done, with the focus of the paper being the modification of the production function by using stochastic frontier analysis (SFA).

¹ PHP 50,000.00 (Philippine Peso) is equivalent to USD 1,004.82 based on December 2016 exchange rate (USD 1.00 = PHP 49.76).

Analytical Framework

The relationships between the inputs and outputs of a producer can be defined as a production function. The theory of production in economics explains the principles by which a business firm or a producer decides how much of its commodity it will produce and sell, and how much of each kind of input (i.e., labor, raw material, fixed capital good, and other inputs) it should employ. The production function is typically written in its basic form as:

$$Q = f(X_1, X_2 \dots X_n) \quad (1)$$

where X_i ($i=1, 2, \dots, n$) are the production inputs, while Q is the production output.

Furthermore, firm theory in economics assumes the following to demonstrate diminishing marginal returns of:

$$\partial Q / \partial X_i > 0 \quad (2)$$

$$\partial^2 Q / \partial X_i^2 < 0 \quad (3)$$

Equation (1) states that the quantity of a firm's output Q is a function of the quantities of its variable inputs X_i . The production function presupposes technical efficiency and states the maximum output obtainable from every possible input combination. Equation (2) states that output increases as the quantity of each input increases. Equation (3) shows that the law of diminishing returns is at work, such that the rate at which output increases declines as the quantity of input increases.

The production function is usually measured using least squares estimation techniques composed of an error term assumed to be symmetrically distributed with zero mean (Kumbhakar and Lovell 2000). However, the possibility remains that not all producers are successful in utilizing minimum inputs to produce the required output. In order for a producer to optimize production, production should be analyzed from the traditional function toward the frontier. With this reformulation, it is no longer applicable to

analyze producer behavior with an error term that is symmetrically distributed with zero mean. The implication of using ordinary least squares (OLS) in the estimation of production function based on the assumption of a symmetrically distributed error term with zero mean will cause a producer's output to end up below the estimated production frontier.

This study adopted the stochastic production frontier model of Irz and McKenzie (2003) specified as:

$$Y_i = f(X_i; \beta) e^{(v_i - u_i)} \quad (4)$$

where

Y_i = output of pond;

X_i = vector of input quantities used by farm i ;

β = vector of parameters to be estimated;

e = composed error term, $(v_i - u_i)$;

v_i = $(-\infty < v < \infty)$ a two-sided normally distributed random error assumed to capture exogenous factors outside of the control of the producer (e.g., weather shocks, natural disasters, and luck);

u_i = one-sided ($u \geq 0$) random component that captures the technical inefficiency of the farmer. The distance (short-fall in output) of a given farm below the stochastic frontier that characterizes "current best practice" given by $(X_i; \beta) e^{v_i} = Y_i^*$. Inefficiency term is assumed to be a normal random variable $N(\mu_i; \sigma_u^2)$ truncated at zero, where $\mu_i = z_i \delta$ and z_i is a vector of farm-specific variables that affect efficiency while δ is a vector of parameters to be estimated; and

Y_i^* = maximum output achievable given the existing technology $f(\cdot)$, the input vector X_i and the random shock v_i affecting farm i .

Using SFA, the error terms in Equation (4) are "composed" error terms, which comprise of

a traditional symmetric random-noise component (i.e., intended to capture the effects of random variation in the operating environment used in the least square estimation of production functions) and an introduction of a one-sided error component intended to capture inefficiency effects. The composed error terms cannot be symmetric and cannot have zero means. The production frontier must be negatively skewed with nonzero means (Kumbhakar and Lovell 2000).

Technical inefficiency (output-based approach) is when producers fail to produce on the frontier isoquant that would maximize revenue, while allocative inefficiency (input-based approach) is when producers fail to choose the best combination of inputs in order to minimize cost (Irz and Stevenson 2009). Technical efficiency is measured as:

$$\begin{aligned} TE_i &= \frac{Y_i}{Y_i^*} \\ TE_i &= \frac{f(X_i; \beta)e^{v_i - u_i}}{f(X_i; \beta)e^{v_i}} \\ TE_i &= e^{-u_i} \\ 0 &\leq TE_i \leq 1 \end{aligned} \quad (5)$$

Equation (5) takes values between 0 and 1, if $TE_i = 1$, then farm i is perfectly efficient, producing on the production frontier; if $TE_i = 0$, then farm i is perfectly inefficient.

To identify the determinants of inefficiencies, the model assumes that u_i s are obtained by truncation at zero of a normal variable $N(\mu_i; \sigma_u^2)$, where:

$$\mu_i = z_i \delta \quad (6)$$

In equation (6), the term z_i denotes a vector of observable explanatory variables, while δ is a vector of parameters to be estimated. The production function is specified as:

$$Y = f(X_i; \beta)e^{v_i - u_i} \quad (7)$$

$$\ln Y_i = \beta_0 + \sum_{j=1}^5 \beta_j \ln(X_{ij}) + \varepsilon_i \quad (8)$$

Equation (8) is the linearized Cobb-Douglas model.

Figure 1 presents the production frontier of tilapia aquaculture in Nueva Vizcaya. In a production function, it is assumed that the primary means of increasing production output in a pond culture is to utilize the best combination of conventional production inputs. However, in reality, not all producers are successful in utilizing minimum input to obtain the required output. Kumbhakar and Lovell (2000) suggest to recast the analysis of production from the traditional function to the frontier. The econometric implication

Figure 1. Production frontier of tilapia aquaculture in Nueva Vizcaya

of the proposed recasting is the addition of a new one-sided inefficiency component to the traditional symmetric random shocks in the operating environment. It is a random component that captures technical inefficiency of the farmer, which are the “producer-specific” variables, namely, operator’s experience in aquaculture; frequency of the manager’s visits to the farm; production intensity; pond quality; age of fishpond owner; educational attainment; and social capital (i.e., membership in organization, social trust, and availability of social support system). Social capital used by the farm is incorporated as an additional determinant of technical efficiency.

One strength of the stochastic frontier models is that they make model estimation more realistic. Furthermore, they build on the set of parametric methods of analysis for technical efficiency of production, which contrasts with the non-parametric methods. Given the noisy nature of the data, the stochastic frontier production function methodology was applied to allow for random shocks. The SFA methodology was selected over data envelopment analysis (DEA) because the latter suffers from two main limitations: (1) any deviation from the frontier is interpreted as inefficiency, which introduces a severe bias in efficiency measurement when production is subject to random shocks (i.e., noise); (2) it does not permit statistical inferences to be drawn and as a consequence, does not support tests of hypotheses concerning the structure of the technologies in question. The weakness of SFA, however, is that it is difficult to find proxies for technical efficiency variables like social capital.

Empirical Model

This study explicitly adopts the determinants of technical efficiency developed by Irz and McKenzie (2003) and additional variables proposed by Theodoridis et al. (2016), but certain modifications are introduced. Social capital (social trust, social networks, credit accessibility, and community trustworthiness) is incorporated as an additional variable of technical efficiency. Household access to credit for investment and growth purposes (Bauer 2016), social network

(membership in an organization), and trust-building are used as proxy variables for social capital.

Initially, the data are initially subjected to multiple regression analysis using OLS to determine the effect of the independent variables (land area, labor, and capital) on the dependent variable (harvest). A skewness test on OLS residuals was used to determine the validity of using stochastic production frontier model (Lin and Schmidt 1984 as cited by Kumbhakar and Lovell 2000). According to Kumbhakar and Lovell (2000), OLS does not provide estimates of producer-specific technical efficiency. To improve the model using OLS estimation procedure, it is suggested that technical efficiency variables be introduced into the econometric equation. This stochastic production frontier model was developed to account for the fact that the highest level of production is not achieved in reality because of technical efficiency factors. In other words, the production function estimated simply by OLS implies that the output is always the best possible output of fishpond operators, when in reality, output is also affected by non-economic factors.

Belotti et al. (2012) postulate that the stochastic frontier models are becoming a widely used tool for efficiency analysis and are usually measured using likelihood estimation to make inferences on frontier parameters and inefficiency. This is different from the estimation strategy with OLS in which parameters are derived through a minimization of the sum of square residuals to find a best-fitting regression line. In their overview of the model, Belotti et al. (2012) explain that the estimation of the production function under SFA uses maximum likelihood strategies, which rely on the maximization of the log-likelihood function derived from the assumption that the observed values of the dependent variable conditional on the model parameters follow the normal distribution. In this case, the log-likelihood function is:

$$\log \mathcal{L} = -\frac{n}{2} \log(2\pi) - \frac{n}{2} \log(\sigma^2) - \frac{1}{2\sigma^2} \sum_{i=1}^n (y_i - \beta_1 x_{i1} - \dots - \beta_j x_{ij})^2 \quad (9)$$

Here, the starting point of the estimation strategy according to Belotti et al. (2012) is estimating the parameters by maximizing the likelihood function of the parameters, including the variances of the two error terms (i.e., to maximize $\ell(\theta)$ where $\theta = \beta_j, \sigma^2$ and $\sigma^2 = \sigma_v^2 + \sigma_u^2$). Therefore, it must mean that point estimates of inefficiency can be derived through the distribution of the technical inefficiency shock conditional on the composite error term $f(u_i|\varepsilon_i)$.

The production frontier estimated is specified below:

$$\ln Y_i = \beta_0 + \sum_n \beta_n \ln X_{ni} + \varepsilon_i \quad (10)$$

$$\ln Y_i = \beta_0 + \sum_n \beta_n \ln X_{ni} + v_i - u_i \quad (11)$$

where:

β = vector of parameters to be estimated

Y_i = volume of production (total harvest from previous to current, in kilogram) of farm i is used instead of gross annual income from aquaculture. This is with the assumption that the market price of tilapia between the two cycles (previous and current) remain the same.

X_i = refers to quantity of input used by farm i , such as quantity of fingerlings and fry; feeds; all other intermediate inputs (fertilizers, poisons, and energy); labor; and land input (pond area in square meter used in production). Since the data was collected over a short period of time, it was assumed that farms faced similar input and output prices and, in this context, aggregation in value is appropriate. The five inputs used in the study were:

X_1 = number of the fingerlings and fry used in the production process;

X_2 = quantity of feeds (in kilogram);

X_3 = quantity of all other intermediate inputs (fertilizers, poisons, energy, in kilogram);

X_4 = labor hired (man-hour/day);

X_5 = land input (pond area in square meter) used in production; and

ε_i = “composed” error term ($v_i - u_i$)

Equation (6) is adopted with the given assumption that the u_i s in the error term are obtained by truncation at zero of a normal variable $N(\mu_i; \sigma_u^2)$. Equation (6) defines the “producer-specific” random shocks in the analysis (Kumbhakar and Lovell 2000). The term z_i denotes a vector of observable explanatory variables, while δ is a vector of parameters to be estimated. Equation (12) is formed by inserting Equation (6) into Equation (11):

$$\ln Y_i = \beta_0 + \sum_n \beta_n \ln X_{ni} + v_i - z_i \delta \quad (12)$$

The following variables are the potential determinants of technical efficiency:

Z_1 = experience in aquaculture, measured in years

Z_2 = frequency of the manager’s visits to the farm, measured as the number of occurrences per week

Z_3 = cost of all intermediate inputs (fingerlings/fry, feeds, fertilizers, energy, poison) per square meter to measure production intensity

Z_4 = corresponds to the construction cost (per square meter)—a variable introduced as a proxy for pond quality (water level in particular)

In the specific case of construction cost as the proxy for pond quality, it was presumed that the larger the amount of money used in construction cost, the higher the quality since higher-quality materials and better workmanship have been used in the construction. Because of the absence of fishing grounds, such as sea, bay, or gulf, the province does not produce or operate commercial fishing suited to deep-sea or open-ocean conditions. Majority of fishpond owners in the province are practicing a pond culture system. There are two types of enclosure being practiced in Nueva Vizcaya, namely, freshwater fish cage and freshwater fishpond. Between 2004 and 2015, pond culture represented almost all of the aquaculture in the province, accounting for 99.6

percent of the total recorded fish production (BAS 2006, 2007, 2009, 2011; PSA 2014, 2016a). Two reasons why locals keep operating their fishponds are (1) availability of vast land area suitable for pond culture; and (2) higher profit, compared with rice production. Belton et al. (2011) showed that although the operating costs of intensive pond management involving pellet feeding are considerably high, yields per hectare are also high. Bisquera (2016, pers. interview) also posits that if pond culture is well-managed, a fish farm operator can earn as much as 200 percent return on investment. Nonetheless, it is imperative to monitor appropriate water quality because the growth of tilapia is reliant on stocking rates, food availability, and water quality, particularly its temperature. The optimum temperature suitable for tilapia is 25°C–30°C; thus, high water temperature could result in high mortality (Bisquera 2012, pers. interview).

This study also introduces variables, such as age and educational attainment of the fishpond owner, as additional determinants of technical efficiency (Theodoridis et al. 2016), where:

Z_5 = age of fishpond owner (years)

Z_6 = educational attainment (maximum educational attainment)

The model of Irz and McKenzie (2003) suggests that all inputs have the expected positive sign, which implies that an increase in any of the five inputs results in increased output. However, the technologies used between brackish and freshwater aquaculture vary substantially. Brackish water aquaculture depends mainly on the natural productivity of ponds improved by fertilizer utilization, while freshwater aquaculture depends mostly on feeds utilization due to the large number of fish stocked.

In identifying the determinants of technical efficiency, the manager's experience and the frequency of his visits to the farm are the only statistically significant variables in reducing inefficiencies. Experienced farmers who monitor farm operations frequently achieve higher levels of technical performance.

Theodoridis et al. (2016) suggest that the expected sign for age is negative, which means that younger farmers are more efficient compared with

older farmers, because they are better educated and more inclined to use new technology and modern production management strategies to increase their farm efficiency. Older farmers are conservative and less receptive to new technologies and strategies.

Farmer's experience has a positive sign and is statistically significant, which is in line with the findings of Irz and McKenzie (2003). The estimated coefficient of education is also positive and significant, which indicates that farmers with more years of schooling tend to be more efficient.

This study incorporates social capital used by farm i as an additional determinant of technical efficiency in the analysis. Social capital, one of the contributory assets in the concept of livelihood, includes social networks, which are associations in which fish farm operators participate and access various types of capital, opportunities, and resources for potential gain (Ellis 2000). Variables Z_7 to Z_{11} are proxy variables that are used in the interpretation and measurement of social capital:

Z_7 = access to credit (with existing loan)

Z_8 = social network (membership in organization, friends, or relatives)

Z_9 = social trust or level of trust in the community, measured on a 5-point Likert scale (5 = strongly agree; 1 = strongly disagree)

Z_{10} = social support or availability of support system, measured on a 5-point Likert scale (5 = strongly agree; 1 = strongly disagree)

Z_{11} = community trustworthiness, measured on a 5-point Likert scale (5 = strongly agree; 1 = strongly disagree)

The generalized likelihood ratio test was the specification test performed in this model. This allows a comparison between a null hypothesis for restrictions on parameters (H_0) against an unrestricted alternative (H_1), based on the following:

$$LR = -2\{\ln(L(H_0)) - \ln(L(H_1))\} \quad (13)$$

where:

$L(.)$ = the value of the log-likelihood function, wherein the test statistic is compared to a critical value obtained from a chi-square distribution.

This study is a cross-sectional analysis of small and large fish farm operators in Nueva Vizcaya. Cross-sectional data provide a snapshot of producers and their efficiency (Kumbhakar and Lovell 2000).

Prices are assumed constant because respondents face similar prices of inputs and output. Hence, the determinants of profitability are the same with that of production.

Belotti et al. (2012) suggest that in cross-sectional data, the new Stata command “*sfcross*” should be used for the estimation of stochastic frontier models. This shows that the “*sfcross*” command is similar to the official frontier command functionality, but with additional new features, such as: (1) estimation of normal-gamma models via simulated maximum likelihood, (2) the estimation of the normal-truncated normal model, and (3) the opportunity to manage complex survey data characteristics (via the “*svyset*” command).

In the econometric analysis of cross-sectional data between yield and inputs (such as land, labor, fertilizer use, and farmer’s education), Baltagi (2005), citing Deaton (1995), noted an indirect relationship between yield and land. This implies that the smaller the input, the higher the yield; hence, small farmers are more productive. This is explained by the fact that a small farm requires less monitoring, which may be done by family labor, compared to large farms that need hired laborers. On the other hand, Deaton (1995) has observed that the regression analysis has omitted the variable “land quality”, which is systematically correlated with farm size. In conclusion, Baltagi (2005) asserted that farm sizes usually show little or no effect over a short period of time.

Survey

Survey instrument and procedure

Data needed for the empirical model were obtained from both primary and secondary sources. Primary data were collected from a field survey

and adopted the survey questionnaire designed by Palanca-Tan (2016). The questionnaire had two parts: part 1 includes the profile of the fish farmer, inputs, and output of production; while part 2 covers questions on social capital.

The fish farmers’ survey was used to evaluate the socioeconomic profile of the fish farm owners, profitability, and production efficiency. Secondary data, such as fish production (provincial and regional), were taken from PSA (2016) and the annual reports of the Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR) (2017).

Sampling procedure

This study used a cross-section analysis of data gathered from fish farm owners of aquaculture ponds in the 10 municipalities of the province of Nueva Vizcaya, namely, Bagabag, Bambang, Bayombong, Diadi, Dupax del Norte, Dupax del Sur, Quezon, Solano, Sta. Fe, and Villaverde. Lists of aquaculture farm operators were secured from BFAR in Bayombong, and from the Municipal Agricultural Offices of Bagabag and Villaverde. However, these lists were not updated and could not fully account for changes overtime. Some fish farmers in the lists were no longer operating their fishponds, while there were also active aquaculture fish farm owners who were not on the list. In effect, the actual number of active aquaculture fish farmers cannot be ascertained from the list, which made it difficult to determine an appropriate sample size. In the absence of an updated list from concerned agencies, this study targeted a total of 250 aquaculture farm operators by referrals to more or less cover all known operators. To attain the targeted sample size, this study used purposive or convenience non-random sampling method to identify existing fish farm operators in the municipality who were not in the list. This study adopted the sampling procedure used by Luttrell (2006) in which respondents were selected and identified using snowball sampling,² following a

² According to Luttrell (2006) citing Eland-Goossense et al. (1997) and Faugier and Sargeant (1997), this technique is a non-random method of data collection whereby interviewees are asked to nominate further informants.

Table 1. Distribution of respondents by municipality

Municipality	No. of Respondents	Percent
Bagabag	31	15.35
Bambang	19	9.41
Bayombong	12	5.94
Diadi	9	4.46
Dupax del Norte	8	3.96
Dupax del Sur	1	0.50
Quezon	39	19.31
Solano	39	19.31
Sta. Fe	2	0.99
Villaverde	42	20.79
Total	202	100

respondent-driven³ procedure until saturation of the target sample was reached. This was to avoid interviewing respondents who were not engaged in fish farming (Orchard et al. 2014, 2015).

Due to time and budget constraints, which were aggravated by peace and order concerns due to alleged sightings of armed groups in some areas, 202 household farm-level operators were included in the study (Table 1).

Household or farm-level surveys ($n = 202$) were collected to identify general household information (age, gender, education, and income); aquaculture production pattern; current income and livelihood activities; and social capital. The

same respondents were revisited for additional variables (i.e., number of cycles, labor, depth of water, and other inputs). Face-to-face interviews were conducted by experienced enumerators.

Data Analysis

The datasets were initially subjected to OLS regression analysis (Table 7) to determine the effect of the independent variables, which include quantities of fingerlings, feeds, and fertilizers; number of hired labor; land input; and social capital (access to credit, social network, social trust, and availability of social support as proxy variables), on the dependent variable (harvest). However, since the OLS estimation procedure could not provide estimates of producer-specific technical efficiency, technical efficiency variables using stochastic production frontier were introduced to improve the model via Equation (6). The results of the stochastic frontier model estimation are shown in Table 8, which should be contrasted with Table 7 that still assumes that the disturbances are two-sided random shocks. The analyses were estimated using STATA.

Empirical Results

Socioeconomic Profile

Tables 2 and 3 present the socioeconomic characteristics of the operators of tilapia fish farms surveyed in the 10 municipalities of Nueva Vizcaya. Operators of fishponds, on average, were relatively

Table 2. Household's characteristics

Variable	Obs	Mean	Std. Dev.	Min	Max
Respondent's Gender: =1 if Male, 0 if Female	202	0.94	0.24	0	1
Age	202	49.73	11.74	26	78
HH size	202	3.97	1.49	1	8
With other employment: =1 if Yes, 0 if No	202	0.92	0.27	0	1
Length of stay in the area (in years)	202	37.83	19.68	1	72

³ That is, until the same names started to reoccur in the list of names provided by respondents (Orchard 2015).

Table 3. Education and sources of income

Variable	Frequency	Percent
<i>Educational attainment (maximum educational level):</i>		
College graduate	67	33.17
Elementary graduate	9	4.46
High school graduate	58	28.71
Some high school	19	9.41
Some college	25	12.38
Some elementary	10	4.95
Technical-vocational	14	6.93
Total	202	100
<i>With other employment:</i>		
Yes	186	92.08
No	16	7.92
Total	202	100
<i>Other sources of income:</i>		
Farm income	156	83.87
Non-farm income	30	16.13
Total	202	100
<i>Non-farm income:</i>		
Business income	9	30.00
Pension	1	3.33
Rural wage/salary employment	20	66.67
Total	30	100

old (49.7 years old), male (94.0%), and had college (33.2%) and high school education (28.7%). Majority of the respondents had other sources of income—either farm income (83.9%) or non-farm income (16.1%). An open-ended question was asked to differentiate between respondents' various income types. Ellis' (2000) categorization was used. Farm income is "income generated from own-account farming, whether on owner-occupied land or land accessed through cash or share tenancy, and includes livestock as well as crop income." On the other hand, non-farm income is non-agricultural income, such as non-farm rural wage or salary employment, business income, rental income, remittances from within the country, pension, and international remittances. Many respondents were involved in rice farming

or integrated livestock and crop farming equivalent to 83.9 percent of farm income, while others were also engaged in non-farm income, either as private or government employees or business entrepreneurs. Out of 193 respondents with relatives working abroad, 60 respondents (71.4%) received international remittances. Household size was small with an average of four members. More than half of the respondents were old (50–78 years of age) are living alone, separate from their married children. Respondents have been staying in the area for an average of 37.8 years.

Almost all respondents had access to basic services, such as electricity (99.5%) and water (99.5%) connections from private sources, and had more than one electric appliance (e.g., television, radio, electric fan, and other appliances). In terms of sanitation, all of the respondents had toilets (100%) and septic tanks (100%). About three-fourths of the households owned a motorcycle, and also used other vehicles. More than 80 percent of the respondents used cellular phone as a means of communication (Table 4).

Farm characteristics

The average fishpond area was 1,896 m², adjacent to an irrigation system and rice fields. Figure 2 shows the frequency distribution of pond area and the cost of constructing a structured pond.

To ensure that the model is not affected by variables other than the usual farm characteristics, outliers had to be dropped from the model. To identify the outliers in the data for pond size, the z-score was computed and those that had values above three were dropped. After dropping the outliers, the new average area of the pond became 1,488 m². Half of the farmland (owned by the fish farmers) surveyed were engaged in an agricultural activity, such as producing rice, vegetables, or livestock, either for domestic consumption or trade. The remaining half of the farmland specialized in tilapia production. Each farm operator maintained an average of 2 fishpond holes⁴ per fish farm.

⁴ Fishpond hole is a description used by fish farmers to measure the number of earthen or structured ponds in a farm.

Table 4. Basic services and appliances owned by households

Variable	Obs	Proportion (%) of Households	Mean	Std. Dev.	Min	Max
Electric connection: =1 if Yes, 0 if No	202	100	0.9950	0.0704	0	1
Main water connection: =1 if Yes, 0 if No	202	100	0.9950	0.0704	0	1
Private water source: =1 if Yes, 0 if No	202	100	0.9950	0.0704	0	1
Sanitation(toilet): =1 if Yes, 0 if No	202	100	1.0000	0.0000	1	1
Toilet with septic tank: =1 if Yes, 0 if No	202	100	1.0000	0.0000	1	1
<i>Entertainment item:</i>						
Radio	202	90	1.0396	0.5629	0	4
TV	202	99	1.4010	0.7996	0	6
Videoke	202	7	0.0842	0.3424	0	3
Electric fan	202	95	2.1881	1.4297	0	8
Sala set	202	87	1.0198	0.5459976	0	3
Aircon	202	18	0.2673	0.7713	0	7
<i>Kitchen and other HH items:</i>						
Refrigerator	202	81	0.9059	0.5519	0	4
Gas stove	202	95	1.0941	0.4417	0	2
Rice cooker	202	76	0.8218	0.5624	0	4
Washing machine	202	87	0.9059	0.4186	0	3
Sewing machine	202	13	0.1436	0.3917	0	2
<i>Communication item:</i>						
Cellphone	202	90	2.6386	2.1425	0	20
Computer	202	40	0.5297	0.8235	0	6
<i>Mode of transportation (multiple answers allowed):</i>						
Motorcycle	202	74	0.9158	0.7178	0	4
Tricycle	202	39	0.4356	0.6296	0	4
Jeep	202	10	0.1238	0.3984	0	3
Tractor	202	34	0.5545	1.0507	0	9
Car	202	24	0.3020	0.6091	0	3

Figure 2. Frequency distribution of pond area and cost of construction **Table 5. Farm income and expenditure**

Variable Name	Mean	Std. Dev.	Min	Max
Harvest (in kg/farmer)	3,036.30	4,093.77	50	37,800
Harvest (in PHP/farmer)	249,022.90	354,417.10	1,300.00	3,333,616.00
No. of fish/kg	4.084	0.278	4	5
Production cycle/annum	1.995	0.704	1	2
Selling price (PHP/kg)	94.13	8.35	70.00	135.00
No. of fingerling (piece/farmer)	17,888.61	24,989.15	1,500	234,000
Cost of fingerling (pc/size)	0.566	0.196	0	1.50
Cost of fingerling/farmer	5,524.53	8,877.62	0	93,800
No. of feeds (kg/farm)	7,303.06	9,836.73	750	93,600
Cost of feed (PHP/sack)	795.43	53.27	420.00	880.00
Cost of feed per farmer	62,276.91	86,161.89	1,580	804,000
Labor (man-hour/day)	3.57	2.52	1	13
Cost of labor (PHP/day)	21.62	58.33	0	250.00

Less than 2 percent of the fishponds were newly built (less than one year old), while the remaining 50 percent were more than five years old. The oldest pond was 45 years old. The average cost incurred in constructing one pond area was PHP 74,347 (after dropping the outliers).

Nearly 7 percent of the fish farm operators had built 5–9 fishpond holes and incurred as much as PHP 758,676 in construction cost. Only 2.5 percent of the respondents inherited their farm from their parents and incurred zero cost; hence, their costs were estimated based on existing pond structures.

Table 5 shows the respondents' farm income and expenditures. The average harvest was 3,036 kg per farmer. The cost per piece of fingerling depended on the size, with the smallest fingerling or fry available in the market priced at PHP 0.50 per piece. BFAR distributed free fingerlings but some fish farm operators opted to buy quality fry from a private nursery or supplier. Of the 202 respondents, only two benefited from the free fingerlings program of BFAR. The average cost of commercial feed available in the market was PHP 795 per sack. Fish farm operators often negotiated with the feed supplier for discounts

on commercial feed or a pay later (after harvest) scheme. There were only two production cycles per year.

Before harvest, a middleman would usually visit the farm to check on the marketable size of tilapia. Most (88.1%) of the fish farm operators dealt with a middleman while the remaining fish farmers sold their harvest in the public market (5.4%) or around the neighborhood (6.4%).

Many of the respondents operated their aquaculture farm through their own income or savings (86.6%), while only 13.1 percent of the farms were funded by another person through loans. The capital for input (feeds and fingerlings) were borrowed from informal creditors or feeds dealer (48.2%), banks (22.2%), cooperatives (18.5%), the Nueva Vizcaya Aquaculture Fisherfolk Association (3.7%), and relatives (7.4%). Respondents also had existing loans (26.7%) borrowed from credit unions, informal creditors, and banks for the purpose of maintaining and operating their farm (74.1%).

Profitability

Table 6 presents the farm budget in tilapia aquaculture. Majority of the respondents harvested every four months, at the most, with at least two cycles per year. The average market price of tilapia was PHP 94.13 per kg. The average harvest per fish farm operator per production cycle was 2,810.13 kg, equivalent to PHP 249,022.90. Majority produced at the commercial scale. Land was usually owned and inherited by fish farm operators. Hence, opportunity cost for the use of land was also included.

The cost of fingerlings accounted for 7.15 percent of the total cost while commercial feeds cost was 80.6 percent due to intensive feeding. According to a key informant, rapid production of plankton is done using basal fertilizer; chicken manure as fertilizer is no longer used in the area.

The profit margin for an average fishpond size of 1,896 was 69 percent. Despite the different challenges that a fish farm operator may face (e.g., natural entry of rice paddy eel locally called

Table 6. Farm budget in freshwater aquaculture

Average Gross Income (PHP)	249,022.90
Quantity (kg)	2,810.13
Price (PHP/kg)	94.13
<i>Cash cost (PHP)</i>	
Fingerlings	5,524.53
Commercial feeds	62,276.91
Fertilizers	a/
Hired Labor	a/
Opportunity cost of land b/	9,478.00
Total cost (PHP)	77,279.44
Net income (PHP)	171,743.46
Cost/kg of fish (PHP)	27.50
Profit margin (%)	68.97

Note:

a = Out of 202 respondents: 6 farmers use fertilizer; 27 farmers hire labor

b = in the absence of land rent, opportunity cost of land was estimated based on interviews with rice farmer operators (i.e., PHP 50,000 net income from good harvest/rice land area of 10,000 m² × average pond area)

kiwit,⁵ drought, flood, and typhoon), there is still a significant profit from operating a tilapia fishpond.

Nueva Vizcaya is a watershed area surrounded by mountain ranges, resulting in abundant water supply favorable to tilapia production. High quality water sources contribute to high aquaculture production. Water is sourced from groundwater, reservoirs, local streams, and irrigation systems. Fish farm operators also practice proper waste management and sanitation (all respondents had septic tanks).

Bush and Kosy (2007) identified access to water as a major contributor to a successful aquaculture production. Thus, the lack of

⁵ Also called Asian swamp eels (*Monopterus albus*), these have been cooked as a delicacy in the past, but are now considered as pest. They reproduce quickly and can grow up to 40 cm. Additionally, they burrow deep into the mud, creating holes that cause rice paddies and irrigation dikes to collapse (Gascon 2011).

consistent water supply is a main constraint in small-scale aquaculture. Moreover, the location of the pond and its surrounding environment, especially if situated near irrigation canals, have a strong influence on productive pond culture.

Social capital

Social capital is a multi-dimensional concept divided into two components: structural and normative. Structural social capital is defined as social network relationships with members, friends, and neighbors, and is further classified based on strength (i.e., bonding, linking, and bridging). Normative social capital is described as trust, trustworthiness, and shared values (Nenadovic and Epstein 2016). It is described as a “social glue” (Afanas’ev, Guzhevina, and Mekhova 2016) from which individuals participate and draw support (Ellis 2000) to achieve private and collective objectives (Roper Center for Public Opinion Research 2017).

Figure 3 shows that fish farm operators identified relatives outside of the province (97.0%) and friends (99.5%) as their social network. In terms of trustworthiness, they believed that they could be trusted by friends or relatives to lend them money, and all respondents felt they could borrow money (PHP 500 and up), if necessary. When in need, fishpond operators sought help from family, close friends, and others. Key informants agreed on the importance of social capital. When their production was greatly affected by the early onset of El Niño in 2010 and super typhoon Lando in 2015, the fish operators coped by borrowing

money from family, friends, and neighbors. Almost all (99.5%) of the respondents could trust their relatives and friends to lend them money. Furthermore, respondents lent to friends and relatives an average of PHP 3,579 and a maximum amount of PHP 100,000.

As suggested by Taylor, Funk, and Clark (2007), social trust is analyzed in relation to the demographics of the population, such as age, race, income, and location (rural or urban areas).

Figure 4 shows the distribution of the sampling population by using a modified social capital index adopted from Taylor, Funk, and Clark (2007). In relation to age, the level of social trust was interpreted using the social capital index measured by using a 5-point Likert scale (5 = strongly agree, 4 = somewhat agree, 3 = neutral, 2 = somewhat disagree, 1 = strongly disagree).

In rating their community, the respondents were asked three questions: (1) Generally, in your opinion, residents in your community can be trusted; (2) Generally, in your opinion, residents in your community are willing to help in times of need; (3) In your opinion, in terms of lending money, most of the residents in your community cannot be trusted.

Majority (78.3%) of the respondents somewhat disagreed that people in their community can be trusted; one fish farmer commented about the difficulty in trusting people nowadays. The population were neutral (56.3%) and somewhat disagreed (37.5%) that the community offered them a support system. Majority (85.25%) of the respondents (both young and elderly) were neutral when asked about community trustworthiness in terms of lending money.

Bridging network, described as membership in formal and informal organizations (Racelis and Labastilla 2017), as an example of bridging social capital, was evident in the province. More than half of the respondents were members in either formal or informal associations, such as irrigators (70.2%) and fisherfolk associations (14.9%). Material resources (physical or non-physical) and benefits attained in joining the organization included access to water irrigation (69.5%), discounted price of commercial feeds or payment after harvest

Figure 3. Social capital of fisherfolk in Nueva Vizcaya

Figure 4: Social trust index: trustworthy, helpful and untrustworthy

Source: Adopted and modified from Taylor, Funk, and Clark (2007)

to informal creditors or dealers (4.2%), access to credit (7.6%), and free training and acquisition of shared information and ideas (10.2%). Bridging network promotes asset acquisition (such as material resources), savings, and access to credit, which can lead to higher incomes and reduction in household poverty of members of an association (Racelis and Labastilla 2017 citing Grootaert and Bastelaer 2001; Grootaert, Swamy, and Oh 1999).

Estimation results

The results of the OLS and SFA estimation methods are shown in Tables 7 and 8, respectively. The two methods (OLS and SFA) correspond to the equation listed in Methods. The two estimation methods used the same set of variables as provided by Equation (12). Table 7 contains three sets of equations (i.e., Models 1, 2, and 3), while Table 8 contains another three sets of empirical equations (i.e., Models 4, 5, and 6). As explained earlier, the main difference is the estimation methodology. The final results, using the SFA methodology, are shown in Table 8.

Harvest and the variable input land (Ln_Pond_area) did not yield any significant pattern; however, the coefficient is negative, indicating that the omitted variable pond quality (Cost_cnstrn_2012) is systematically correlated with the explanatory variable farm size (Ln_Pond_area) (Baltagi 2005 citing Deaton 1995). The estimated coefficient of farm owner's age in Model 2 is negative, although not significant. According to Theodoridis et al. (2016), younger fish farm owners are more efficient than older fish farm owners. Farmer's experience is statistically significant but was indirectly related to harvest, which is contrary to the findings of Theodoridis et al. (2016) and Irz and Mckenzie (2003). Hence, further investigation is suggested. Social network (with_reltvsCode) was negatively correlated with harvest ($p < .05$), while community trustworthiness (Res_NtrusCode) was positively correlated ($p < .05$).

Using multiple regression analysis in Model 1 (Table 7), the variable input fingerling (Ln_Fingrlng) was significant ($p < .01$). Manager's frequency of visit to the farm (Freq_visCode) and social capital (Res_NtrusCode) were significant (p

Table 7: Estimation of results using OLS

Variable	Parameter	Estimates		
		Model 1	Model 2	Model 3
Constant	β_0	-1.454** (0.600)	-1.697*** (0.406)	-4.364*** (0.800)
Ln_Fingrlng	β_1	0.902*** (0.0955)	0.875*** (0.0952)	0.863*** (0.0910)
Ln_Feed	β_2	0.129 (0.0925)	0.160* (0.0924)	0.169* (0.0879)
Ln_Othr_Input	β_3			
Ln_Labor	β_4	0.0370 (0.0532)	0.0362 (0.0533)	
Ln_Pond_area	β_5	-0.0736 (0.0591)	-0.0669 (0.0610)	-0.0510 (0.0573)
<i>Technical Efficiency</i>				
Exper	δ_1	-0.00627 (0.00393)	-0.00667* (0.00401)	-0.00683* (0.00382)
Freq_visCode	δ_2	0.0157* (0.00909)	0.0158* (0.00907)	0.0130 (0.00878)
Cost_Input	δ_3			
Cost_cnstrn_2012	δ_4			
Age	δ_5	-0.0165 (0.0202)	0.00119 (0.00254)	
Age_sq				1.68e-05 (2.42e-05)
Educ_Code	δ_6		0.0333 (0.0251)	0.0298 (0.0241)
W_LoanCode	δ_7		-0.0508 (0.0684)	-0.0498 (0.0478)
with_reltvsCode	δ_8		-0.318* (0.162)	-0.315** (0.157)
Res_trustCode	δ_9	0.0379 (0.0595)	0.0418 (0.0623)	0.0342 (0.0594)
Res_NtrusCode	δ_{10}	0.108* (0.0563)	0.113** (0.0565)	0.112** (0.0542)
ProdCY	δ_{11}			1.331*** (0.377)

Note: Standard errors in parentheses; *** p<0.01, **p<0.05, *p<0.1

Table 8: Estimation of technical efficiency in production frontier models using cross-sectional data

Variable	Parameter	Estimates		
		Model 4	Model 5	Model 6
Constant	β_0	-4.364*** (0.800)	-4.513*** (0.469)	-3.976*** (0.575)
Ln_FingrIng	β_1	0.863*** (0.0910)	1.011*** (0.0533)	0.897*** (0.102)
Ln_Feed	β_2	0.169* (0.0879)	0.0120 (0.0516)	0.0414 (0.0980)
Ln_Othr_Input	β_3			
Ln_Labor	β_4			
Ln_Pond_area	β_5	-0.0510 (0.0573)	-0.0553 (0.0336)	0.00349 (0.0463)
<i>Technical Efficiency</i>				
Exper	δ_1	-0.00683* (0.00382)	-0.000386 (0.00224)	-0.000998 (0.00312)
Freq_visCode	δ_2	0.0130 (0.00878)	0.00505 (0.00515)	0.0110 (0.00668)
Cost_Input	δ_3			
Cost_cnstrn_2012	δ_4			
Age	δ_5			
Age_sq		1.68e-05 (2.42e-05)	8.19e-06 (1.42e-05)	5.98e-07 (1.85e-05)
Educ_Code	δ_6	0.0298 (0.0241)	0.0214 (0.0142)	0.0274 (0.0184)
W_LoanCode	δ_7	-0.0498 (0.0478)	-0.0396 (0.0384)	-0.0425 (0.0514)
with_reltvsCode	δ_8	-0.315** (0.157)	-0.199** (0.0920)	-0.362** (0.144)
Res_trustCode	δ_9	0.0342 (0.0594)	0.0245 (0.0349)	-0.0138 (0.0395)
Res_NtrusCode	δ_{10}	0.112** (0.0542)	0.0642** (0.0318)	0.105** (0.0413)
ProdCY	δ_{11}	1.331*** (0.377)	1.442*** (0.221)	1.532*** (0.265)

Notes:

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

The variable age was highly correlated due to multicollinearity; hence, excluded from the model.

$< .10$). In Model 2, the variable input fingerling was still significant ($p < .01$), while variable input feed (Ln_Feed), experience of fish farm operator (Exper), frequency of visits to the farm, and social network (with_reltvsCode) were significant ($p < .01$). Social capital (Res_NtrusCode) was significant ($p < .05$). The OLS coefficients of Ln_FingrIng, Ln_Feed, Exper, with_reltvsCode,

and Res_NtrusCode were consistent in Model 3; however the estimated constant (intercept) was not. The production cycle of the fish farm (ProdCY) was added in Model 3 and was found to be significant ($p < .01$).

Some variables, such as other input (Ln_Othr_Input), pond intensity (Cost_Input), educational level (Educ_level), and pond quality

(Cost_cnstrn_2012) were omitted due to presence of collinearity. The relationship between harvest and the variable input land (Ln_Pond_area) did not yield any significant pattern; however, the coefficient was negative, thereby indicating that the omitted variable pond quality (Cost_cnstrn_2012) was systematically correlated with the explanatory variable farm size (Ln_Pond_area) (Baltagi 2005 citing Deaton 1995).

The estimated coefficient of farm owner's age in Model 2 was negative, although not significant. According to the findings of Theodoridis et al. (2016), younger fish farm owners were more efficient than older fish farm owners. Farmer's experience was statistically significant but had indirect relation to harvest, which was contrary to the findings of Theodoridis et al. (2016) and Irz and McKenzie (2003). Hence, further investigation would be warranted.

The coefficient of social network (with_reltvsCode) was negative and statistically significant ($p < .05$). Intuitively, a 1 percent increase in social network decreased aquaculture harvest by 31.5 percent. This may be explained by the culture and tradition of households in terms of sharing resources or lending money to friends or relatives. Instead of investing funds into capital inputs, money is shared or lent to relatives. Also, it is a known practice that fish that are considered not of good quality and size, and are left after the main harvest, were given for free to relatives and friends. This finding conformed with those of Irz and Stevenson (2009).

Respondents' relationship with relatives outside the province was identified as a bonding type of social capital, wherein individuals participated for personal and collective gain. Contrary to the findings of Rosas et al. (2014), the effect of social capital, using the dimension of social network as proxy variable, was found to have a positive relationship on per capita income of fishermen, which implied that greater social capital resulted in greater average per capita income.

Community trustworthiness (Res_NtrusCode) was also positive and significant ($p < .05$), which meant that the more the fish farmer distrusted residents in the community in terms of

lending money, the more that his/her aquaculture harvest increased as he/she would devote greater capital for aquaculture operation. On the other hand, 73.3 percent of the fish farmers did not have an existing loan, and they were willing to lend money up to PHP 100,000, depending on the needs of the borrower and the availability of funds.

The relationship between harvest and trustworthiness of fish farm operators was also estimated using variables such as ability to (1) borrow money from friends or relatives (SN_borrow) and (2) lend money (SN_lend). However, no significant relationship was found between trustworthiness of fish farm operators and harvest; hence, these variables were excluded in the model.

Following the estimation methods suggested by Kumbhakar, Wang, and Horncastle (2015), the estimation of technical efficiency in production frontier models using cross-sectional data began with (1) distribution-free approaches, such as OLS, corrected OLS (COLS), and corrected mean absolute deviation (CMAD); followed by (2) parametric distributional assumptions, such as half-normal distribution, truncated-normal distribution, and exponential distribution.

Model 4 is a standard OLS estimation (Table 8). The results showed that the output elasticity of fingerlings was 0.86. After such OLS estimation, COLS was estimated in order to measure efficiency of each observation. Table 9 shows that, on average, the aquaculture farm operators achieved 33 percent of the maximum potential output in production. The maximum efficiency index was 1 while the least efficient aquaculture farm operators achieved only 5 percent of their maximum achievable output. Figure 5 shows the histogram of the efficiency index, which is negatively skewed.

CMAD is an alternative measure of technical efficiency. It is another regression that estimates efficiency from the residuals of the median (Kumbhakar, Wang, and Horncastle 2015). Comparing the coefficient estimates of Model 5 and Model 4, the variables fingerling (Ln_Fingrlng), social network (with_reltvsCode), and annual production cycle (ProdCY) slightly increased compared to OLS Model 4. However,

Table 9. Corrected OLS

Variable	Observation	Mean	Std. Dev.	Min	Max
eff_cols	199	.3321275	.1118999	.0465969	1

Figure 5. COLS histogram **Figure 6. Comparison of two histograms**

the coefficient estimates of untrustworthiness (Res_NtrusCod) increased (from 6% to 10%) in Model 5.

The results of COLS and CMAD were almost the same. Table 10 and Figure 6 show that, on average, the aquaculture farm operators achieved 35 percent of the maximum potential output in their production. The maximum efficiency index is 1, while the least efficient aquaculture farm operators achieved only 4 percent of their maximum achievable output. Figure 6 shows the histogram of efficiency results from Model 5. As shown in the graph, there are outliers because of dispersion of efficiencies.

A skewness specification test on OLS residuals was used to check the validity of the model's stochastic frontier. Regardless of the distributional assumptions, the residuals from the corresponding OLS estimation should be negatively skewed (Kumbhakar, Wang, and

Horncastle 2015), citing Lin and Schmidt (1984). Using Model 4, the null hypothesis of no skewness was rejected. Hence, the introduction of technical efficiency variables using stochastic production frontier improved the model compared to the OLS estimation procedure. As such, it was recommended to proceed with the estimation of the stochastic frontier model. The negative sign (−1.52) in Table 11 indicated a left-skewed distribution of residuals, hence the null hypothesis of no skewness was rejected. The test also resulted in a p-value less than 0.01, which meant that the skewness was statistically significant.

For the estimation of parametric stochastic frontier model using cross-sectional data, Model 6 was analyzed using the Stata command “frontier”, which was used in the study of Irz and McKenzie (2003).

Table 10: Comparison of corrected OLS and CMAD

Variable	Observation	Mean	Std. Dev.	Min	Max
eff_cols	199	.3321275	.1118999	.0465969	1
eff_cmad	199	.3501162	.1176496	.0417228	1

Table 11: Skewness test on OLS residuals

<i>Ho: Model has no skewness</i>	
95% percentiles	-1.52
p value	0.0000

Table 12: Pairwise correlations of social network with community trustworthiness

Variables	Pairwise Correlation
Social network and community trustworthiness	0.0535

As shown in Table 8, the coefficient estimates of the variable input fingerling (Ln_Fingrlng) and production cycle (ProdCY) were significant ($p < .01$), while social network (with_reltvsCode) and community trustworthiness (Res_NtrusCode) were also significant ($p < .05$) in Model 6.

The pairwise correlation coefficients between social network (with_reltvsCode) and community trustworthiness (Res_NtrusCode) was 0.05, indicating very low correlation (Table 12). This shows that there was no necessary relation between social network and community trustworthiness.

The likelihood ratio test was the post specification test performed in Model 6. Table 13 shows that critical value of the statistic was 5.412 ($p < .01$). The test resulted in a value equal to 9.62, which meant that the null hypothesis of no technical inefficiency (no one-sided error) was rejected (Table 14). There was evidence of one-sided error (u_i), which represented technical inefficiency in the model. Also, the calculated probability (0.0019) was lower than 0.01, which indicated strong evidence against the null hypothesis. Therefore, the test of inefficiency was statistically significant.

Table 14: Likelihood ratio test result

LR chi2(1) =	9.62
Prob>chi2 =	0.0019

For the estimation of parametric stochastic frontier model using cross-sectional data, the coefficient estimates of the variable input fingerling and production cycle are highly significant in explaining the variation of aquaculture harvest of the fish farmer. In identifying the determinants of technical efficiency, social capital measured by social network and community trustworthiness were the only significant variables. The effect of social network on harvest is negative, which implies that a 1 percent increase in social network decreases aquaculture harvest by 31.5 percent. On the other hand, harvest is also strongly determined and explained by community trustworthiness. Findings reveal that the less trusting the fish farmer is of the residents in the community, the greater is his/her harvest.

Conclusion

Results show that the level of fingerling use was highly significant in explaining the variation in harvest. This is consistent with the findings of Irz and McKenzie (2003), suggesting that all inputs have the expected positive sign.

In identifying the determinants of technical efficiency, social capital, measured by social network (with_reltvsCode) and community trustworthiness (Res_NtrusCode), were the only significant variables. The effect of social network on harvest was negative, which implied that a 1 percent increase in social network decreases aquaculture harvest by 31.5 percent. This may be due to the traditional practice of fish farmers of sharing resources to their friends

Table 13: Likelihood ratio test of the inefficiency (post estimation)

df	0.25	0.10	0.05	0.025	0.01	0.005	0.001
1	0.455	1.642	2.705	3.841	5.412	6.635	9.500

Source: Kodde and Palm (1986)

and relatives, thereby diverting resources away from use for production inputs. On the other hand, harvest was also strongly determined and explained by trustworthiness, another dimension of social capital. Findings revealed that the more fish farmers mistrusted the members of their community in terms of lending money, the more that harvest increased as funds for aquaculture operation were not diverted into lending. In other words, the fish farmer devoted his/her funds to necessary operations in the fish farm to increase aquaculture production. This is in consonance with the findings of Bush and Kosy (2007), citing Dey and Ahmed (2005), that the more efficient use of existing inputs and technologies is considered one of four strategies to realize more sustainable and efficient small-scale aquaculture production.

For future research, panel data analysis could further shed light on the performance of fish farm operators in the area. While cross-sectional data provide a snapshot of producers and their efficiency, panel data can provide more reliable evidence on their performance, because they enable one to track the performance of each fish farmer through a sequence of time periods (Kumbhakar and Lovell 2000).

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